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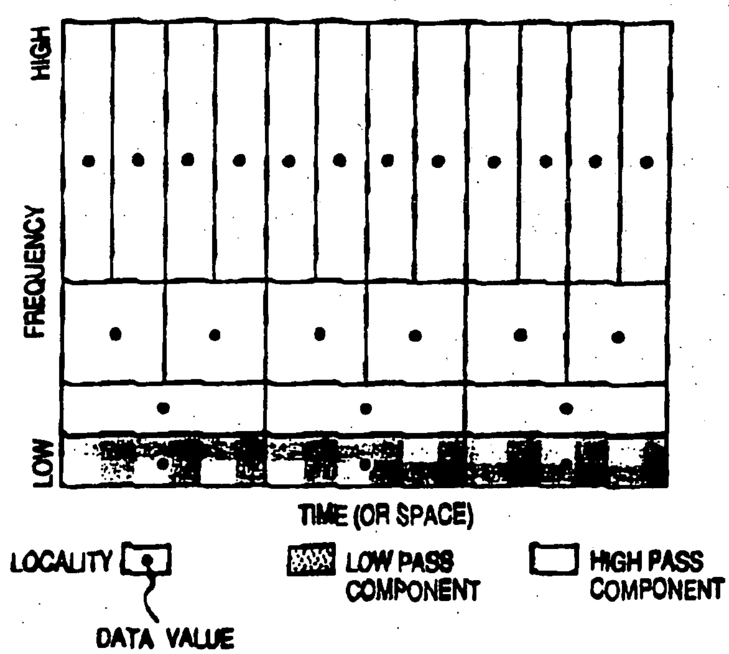
(54) Title: DATA COMPRESSION AND DECOMPRESSION

(57) Abstract

A compression and decompression method uses a wavelet decompositin, frequency based tree encoding, tree based motion encoding, frequency weighted quantization, Huffman encoding, and/or tree based activity estimation for bit rate control. Forward and inverse quasi-perfect reconstruction transforms are used to generate the wavelet decomposition and to reconstruct data values close to the original data values. The forward and inverse quasi-perfect reconstruction transforms utilize special filters at the boundaries of the data being transformed and/or inverse transformed. Structures and methods are disclosed for traversing wavelet decompositions. Methods are disclosed for increasing software execution speed in the decompression of video. Fixed or variable length tokens are included in a compressed data stream to indicate changes in encoding methods used to generate the compressed data stream.



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DATA COMPRESSION AND DECOMPRESSION

CROSS REFERENCE TO APPENDICES

Appendix A, which is a part of the present disclosure, is a listing of a software implementation written in the programming language C.

Appendices B-1 and B-2, which are part of the present disclosure, together are a description of a hardware implementation in the commonly used hardware description language ELLA.

Appendix C, which is part of the present disclosure is a listing of a software implementation written in the programming language C and assembly code.

FIELD OF THE INVENTION

This invention relates to a method of and apparatus for data compression and decompression. In particular, this invention relates the compression, decompression, transmission and storage of audio, still-image and video data in digital form.

BACKGROUND INFORMATION

An image such as an image displayed on a computer monitor may be represented as a two-dimensional matrix of digital data values. A single frame on a VGA computer monitor may, for example, be represented as three matrixes of pixel values. Each of the three matrixes has a data value which corresponds to a pixel on the monitor.

The images on the monitor can be represented by a 640 by 480 matrix of data values representing the luminance

(brightness) values Y of the pixels of the screen and two other 640 by 480 matrixes of data values representing the chrominance (color) values U and V of the pixels on the screen. Although the luminance and chrominance values are analog values, the one luminance value and the two chrominance values for a pixel may be digitized from analog form into discrete digital values. Each luminance and chrominance digital value may be represented by an 8-bit number. One frame of a computer monitor therefore typically requires about 7 megabits of memory to store in an uncompressed form.

In view of the large amount of memory required to store or transmit a single image in uncompressed digital form, it would be desirable to compress the digital image data before storage or transmission in such a way that the compressed digital data could later be decompressed to recover the original image data for viewing. In this way, a smaller amount of compressed digital data could be stored or transmitted. Accordingly, numerous digital image compression and decompression methods have been developed.

According to one method, each individual digital value is converted into a corresponding digital code. Some of the codes have a small number of bits whereas others of the codes have a larger number of bits. In order to take advantage of the fact that some of the codes are short whereas others of the codes are longer, the original digital data values of the original image are filtered using digital filters into a high frequency component and a low frequency component. The high frequency component represents ambiguities in the image and is therefore observed to have a comparatively large number of identical data values for real-world images. By encoding the commonly occurring digital data values in the high frequency component with the short digital codes, the total number of bits required to store the image data can be reduced from the number of bits that would otherwise be

required if 8-bits were used to represent all of the data values. Because the total number of bits in the resulting encoded data is less than the total number of bits in the original sequence of data values, the original image is said to have been compressed.

To decompress the compressed encoded data to recover the original image data, the compressed encoded data is decoded using the same digital code. The resulting high and low frequency components are then recombined to form the two-dimensional matrix of original image data values.

Where the data being compressed is two-dimensional data such as image data, separation of the original data into high and low frequency components by the digital filters may be accomplished by filtering in two dimensions such as the horizontal dimension of the image and the vertical dimension of the image. Similarly, decoded high and low frequency components can be recombined into the original image data values by recombining in two dimensions.

To achieve even greater compression, the low frequency component may itself be filtered into its high and low frequency components before encoding. Similarly, the low frequency component of the low frequency component may also be refiltered. This process of recursive filtering may be repeated a number of times. Whether or not recursive filtering is performed, the filtered image data is said to have been "transformed" into the high and low frequency components. This digital filtering is called a "transform". Similarly, the high and low pass components are said to be "inverse transformed" back into the original data values. This process is known as the "inverse transform".

Figure 1 is a diagram of a digital gray-scale image of a solid black square 1 on a white background 2 represented by a 640 by 480 matrix of 8-bit data luminance values.

Figure 2 is a diagram illustrating a first

intermediate step in the generation of the high and low frequency components of the original image. A high pass digital filter which outputs a single data value using multiple data values as inputs is first run across the original image values from left to right, row by row, to generate G subblock 3. The number of digital values in G subblock 3 is half of the number of data values in the original image of Figure 1 because the digital filter is sequentially moved to the right by twos to process two additional data values for each additional one data output generated for G subblock 3. Similarly, a low pass digital filter which outputs a single data value using multiple data values as inputs is first run across the original image values from left to right, row by row, to generate H subblock 4. The number of digital values in H subblock 4 is half of the number of data values in the original image because the digital filter is moved to the right by twos to process two additional data values for each additional one data output generated for H subblock 4. Each of the two vertical bars in high pass G subblock 3 appears where a change occurs spatially in the horizontal dimension in the original image of Figure 1. Where the G filter encounters a change from white data values to black data values when the filter G is run across the image of Figure 1 in a horizontal direction, the G digital filter outputs a corresponding black data value into subblock 3. Similarly, when the G digital filter encounters the next change, which is this time a change from black to white data values, the G digital filter again outputs a corresponding black data value into G subblock 3.

Figure 3 is a diagram illustrating a second intermediate step in the generation of the high and low frequency components of the original image. The high pass digital filter is run down the various columns of the subblocks H and G of Figure 2 to form the HG subblock 5 and GG subblock 6 shown in Figure 3. Similarly, the low pass digital filter is run down the various columns of the

H and G subblocks 3 and 4 of Figure 2 to form HH and GH subblocks 7 and 8 shown in Figure 3. The result is the low pass component in subblock HH and the three high pass component subblocks GH, HG and GG. The total number of high and low pass component data values in Figure 3 is equal to the number of data values in the original image of Figure 1. The data values in the high pass component subblocks GH, HG and GG are referred to as the high frequency component data values of octave 0.

The low pass subblock HH is then filtered horizontally and vertically in the same way into its low and high frequency components. Figure 4 illustrates the resulting subblocks. The data values in HHHG subblock 9, HHGH subblock 10, and HHGG subblock 11 are referred to as the high frequency component data vales of octave 1. Subblock HHHH is the low frequency component. Although not illustrated, the low frequency HHHH subblock 12 can be refiltered using the same method. As can be seen from Figure 4, the high frequency components of octaves 0 and 1 are predominantly white because black in these subblocks denotes changes from white to black or black to white in the data blocks from which to high frequency subblocks are generated. The changes, which are sometimes called edges, from white to black as well as black to white in Figure 1 result in high frequency data values in the HG, HG and GG quadrants as illustrated in Figure 3.

Once the image data has been filtered the desired number of times using the above method, the resulting transformed data values are encoded using a digital code such as the Huffman code in Table 1.

Corresponding Gray-Scale	Digital Value	Digital Code
	.	
	.	
	.	
	5	1000001
	4	100001
	3	10001
	2	1001
black	1	101
white	0	0
	-1	111
	-2	1101
	-3	11001
	-4	110001
	-5	1100001
	.	
	.	
	.	

Table 1

Because the high frequency components of the original image of Figure 1 are predominantly white as is evident from Figures 3 and 4, the gray-scale white is assigned the single bit 0 in the above digital code. The next most common gray-scale color in the transformed image is black. Accordingly, gray-scale black is assigned the next shortest code of 101. The image of Figure 1 is comprised only of black and white pixels. If the image were to involve other gray-scale shades, then other codes would be used to encode those gray-scale colors, the more predominant gray-scale shades being assigned the relatively shorter codes. The result of the Huffman encoding is that the digital values which predominate in the high frequency components are coded into codes having a few number of bits. Accordingly, the number of bits required to represent the original image data is reduced. The image is therefore said to have been compressed.

Problems occur during compression, however, when the digital filters operate at the boundaries of the data values. For example, when the high pass digital filter generating the high pass component begins generating high pass data values of octave 0 at the left hand side of the original image data, some of the filter inputs required by

the filter do not exist.

Figure 5 illustrates the four data values required by a four coefficient high pass digital filter G in order to generate the first high pass data value G_0 of octave 0. As shown in Figure 5, data values D_1, D_2, D_3 and D_4 are required to generate the second high pass data value of octave 0, data value G_1. In order to generate the first high pass component output data value G_0, on the other hand, data values D_{-1}, D_0, D_1, and D_2 are required. Data value D_{-1} does not, however, exist in the original image data.

Several techniques have been developed in an attempt to solve the problem of the digital filter extending beyond the boundaries of the image data being transformed. In one technique, called zero padding, the nonexistent data values outside the image are simply assumed to be zeros. This may result in discontinuities at the boundary, however, where an object in the image would otherwise have extended beyond the image boundary but where the assumed zeros cause an abrupt truncation of the object at the boundary. In another technique, called circular convolution, the two dimensional multi-octave transform can be expressed in terms of one dimensional finite convolutions. Circular convolution joins the ends of the data together. This introduces a false discontinuity at the join but the problem of data values extending beyond the image boundaries no longer exists. In another technique, called symmetric circular convolution, the image data at each data boundary is mirrored. A signal such as a ramp, for example, will become a peak when it is mirrored. In another technique, called doubly symmetric circular convolution, the data is not only mirrored spatially but the values are also mirrored about the boundary value. This method attempts to maintain continuity of both the signal and its first derivative but requires more computation for the extra mirror because the mirrored values must be pre-calculated

before convolution.

Figure 6 illustrates yet another technique which has been developed to solve the boundary problem. According to this technique, the high and low pass digital filters are moved through the data values in a snake-like pattern in order to eliminate image boundaries in the image data. After the initial one dimensional convolution, the image contains alternating columns of low and high pass information. By snaking through the low pass sub-band before the high pass, only two discontinuities are introduced. This snaking technique, however, requires reversing the digital filter coefficients on alternate rows as the filter moves through the image data. This changing of filter coefficients as well as the requirement to change the direction of movement of the digital filters through various blocks of data values makes the snaking technique difficult to implement. Accordingly, an easily implemented method for solving the boundary problem is sought which can be used in data compression and decompression.

Not only does the transformation result in problems at the boundaries of the image data, but the transformation itself typically requires a large number of complex computations and/or data rearrangements. The time required to compress and decompress an image of data values can therefore be significant. Moreover, the cost of associated hardware required to perform the involved computations of the forward transform and the inverse transform may be so high that the transform method cannot be used in cost-sensitive applications. A compression and decompression method is therefore sought that not only successfully handles the boundary problems associated with the forward transform and inverse transform but also is efficiently and inexpensively implementable in hardware and/or software. The computational complexity of the method should therefore be low.

In addition to transformation and encoding, even

further compression is possible. A method known as tree encoding may, for example, be employed. Moreover, a method called quantization can be employed to further compress the data. Tree encoding and quantization are described in various texts and articles including "Image Compression using the 2-D Wavelet Transform" by A.S. Lewis and G. Knowles, published in IEEE Transactions on Image Processing, April 1992. Furthermore, video data which comprises sequences of images can be compressed by taking advantage of the similarities between successive images. Where a portion of successive images does not change from one image to the next, the portion of the first image can be used for the next image, thereby reducing the number of bits necessary to represent the sequence of images.

JPEG (Joint Photographics Experts Group) is an international standard for still-images which typically achieves about a 10:1 compression ratios for monochrome images and 15:1 compression ratios for color images. The JPEG standard employs a combination of a type of Fourier transform, known as the discrete-cosine transform, in combination with quantization and a Huffman-like code. MPEG1 (Motion Picture Experts Group) and MPEG2 are two international video compression standards. MPEG2 is a standard which is still evolving which is targeted for broadcast television. MPEG2 allows the picture quality to be adjusted to allow more television information to be transmitted, e.g., on a given coaxial cable. H.261 is another video standard based on the discrete-cosine transform. H.261 also varies the amount of compression depending on the data rate required.

Compression standards such as JPEG, MPEG1, MPEG2 and H.261 are optimized to minimize the signal to noise ratio of the error between the original and the reconstructed image. Due to this optimization, these methods are very complex. Chips implementing MPEG1, for example, may be costly and require as many as 1.5 million transistors. These methods only partially take advantage of the fact

that the human visual system is quite insensitive to signal to noise ratio. Accordingly, some of the complexity inherent in these standards is wasted on the human eye. Moreover, because these standards encode by areas of the image, they are not particularly sensitive to edge-type information which is of high importance to the human visual system. In view of these maladaptions of current compression standards to the characteristics of the human visual system, a new compression and decompression method is sought which handles the above-described boundary problem and which takes advantage of the fact that the human visual system is more sensitive to edge information than signal to noise ratio so that the complexity and cost of implementing the method can be reduced.

SUMMARY

A compression and decompression method using wavelet decomposition, frequency based tree encoding, tree based motion encoding, frequency weighted quantization, Huffman encoding, and tree based activity estimation for bit rate control is disclosed. Forward and inverse quasi-perfect reconstruction transforms are used to generate the wavelet decomposition and to reconstruct data values close to the original data values. The forward and inverse quasi-perfect reconstruction transforms utilize special filters at the boundaries of the data being transformed and/or inverse transformed to solve the above-mentioned boundary problem.

In accordance with some embodiments of the present invention, a decompression method uses four coefficient inverse perfect reconstruction digital filters. The coefficients of these inverse perfect reconstruction digital filters require a small number of additions to implement thereby enabling rapid decompression in software executing on a general purpose digital computer having a microprocessor. The method partially inverse transforms a

sub-band decomposition to generate a small low frequency component image. This small image is expanded in one dimension by performing interpolation on the rows of the small image and is expanded in a second dimension by replicating rows of the interpolated small image. Transformed chrominance data values are inverse transformed using inverse perfect reconstruction digital filters having a fewer number of coefficients than the inverse perfect reconstruction digital filters used to inverse transform the corresponding transformed luminance data values. In one embodiment, two coefficient Haar digital filters are used as the inverse perfect reconstruction digital filters which inverse transform transformed chrominance data values. Variable-length tokens are used in the compressed data stream to indicate changes in encoding methods used to encode data values in the compressed data stream.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1-4 (Prior Art) are diagrams illustrating a sub-band decomposition of an image.

Figure 5 (Prior Art) is a diagram illustrating a boundary problem associated with the generation of prior art sub-band decompositions.

Figure 6 (Prior Art) is a diagram illustrating a solution to the boundary problem associated with the generation of prior art sub-band decompositions.

Figure 7 is a diagram illustrating a one-dimensional decomposition.

Figures 8 and 9 are diagrams illustrating the separation of an input signal into a high pass component and a low pass component.

Figures 10, 11, 14 and 15 are diagrams illustrating a transformation in accordance with one embodiment of the present invention.

Figures 12 and 13 are diagrams illustrating the operation of high pass and low pass forward transform

digital filters in accordance with one embodiment of the present invention.

Figure 16 is a diagram of a two-dimensional matrix of original data values in accordance with one embodiment of the present invention.

Figure 17 is a diagram of the two-dimensional matrix of Figure 16 after one octave of forward transform in accordance with one embodiment of the present invention.

Figure 18 is a diagram of the two-dimensional matrix of Figure 16 after two octaves of forward transform in accordance with one embodiment of the present invention.

Figures 19 and 20 are diagrams illustrating a boundary problem solved in accordance with one embodiment of the present invention.

Figure 21 is a diagram illustrating the operation of boundary forward transform digital filters in accordance with one embodiment of the present invention.

Figure 22 is a diagram illustrating the operation of start and end inverse transform digital filters in accordance with one embodiment of the present invention.

Figure 23 is a diagram illustrating a one-dimensional tree structure in accordance one embodiment of the present invention.

Figure 24A-D are diagrams illustrating the recursive filtering of data values to generate a one-dimensional decomposition corresponding with the one-dimensional tree structure of Figure 23.

Figure 25 is a diagram of a two-dimensional tree structure of two-by-two blocks of data values in accordance with one embodiment of the present invention.

Figure 26 is a pictorial representation of the data values of the two-dimension tree structure of Figure 25.

Figures 27-29 are diagrams illustrating a method and apparatus for determining the addresses of data values of a tree structure in accordance with one embodiment of the present invention.

Figure 30 and 31 are diagrams illustrating a

quantization of transformed data values in accordance with one embodiment of the present invention.

Figures 32 and 33 are diagrams illustrating the sensitivity of the human eye to spatial frequency.

Figures 34 is a diagram illustrating the distribution of high pass component data values in a four octave wavelet decomposition of the test image Lenna.

Figure 35 is a diagram illustrating the distribution of data values of the test image Lenna before wavelet transformation.

Figure 36 is a block diagram illustrating a video encoder and a video decoder in accordance with one embodiment of the present invention.

Figure 37 is a diagram illustrating modes of the video encoder and video decoder of Figure 36 and the corresponding token values.

Figure 38 is a diagram illustrating how various flags combine to generate a new mode when the inherited mode is send in accordance with one embodiment of the present invention.

Figures 39-40 are diagrams of a black box on a white background illustrating motion.

Figures 41-43 are one-dimensional tree structures corresponding to the motion of an edge illustrated in Figures 39-40.

Figure 44 is a diagram illustrating variable-length tokens in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

QUASI-PERFECT RECONSTRUCTION FILTERS

The wavelet transform was introduced by Jean Morlet in 1984 to overcome problems encountered in analyzing geological signals. See "Cycle-octave and Related Transforms In Seismic Signal Analysis", Goupillaud, Grossman and Morlet, Geoexploration, vol. 23, 1984. Since then, the wavelet transform has been a new and exciting

method of analyzing signals and has already been applied to a wide range of tasks such as quantum mechanics and signal processing. The wavelet transform has a number of advantages over more traditional Fourier techniques principally used today in the analysis of signals. The wavelet transform and the high and low pass four coefficient quasi-perfect reconstruction filters of the present invention are therefore described by relating them to the windowed Fourier transform.

The windowed Fourier transform is the principle transform used today to analyze the spectral components of a signal. The Fourier transform decomposes a signal under analysis into a set of complex sinusoidal basis functions. The resulting Fourier series can be interpreted as the frequency spectra of the signal. The continuous Fourier transform is defined as follows:

$$F(\omega)=\int_{-\infty}^{+\infty}e^{-j2\pi\omega t}f(t)\,dt \qquad \text{(equ. 1)}$$

Where f(t) is the time domain signal under analysis and F(ω) is the Fourier transform of the signal under analysis. Although many applications require an estimate of the spectral content of an input signal, the above formula is impractical for most systems. In order to calculate the Fourier transform, the input signal f(t) must be defined for all values of time t, whereas in most practical systems, f(t) is only defined over a finite range of time.

Several methods have therefore been devised to transform the finite input signal into an infinite signal so that the Fourier transform can be applied. The windowed Fourier transform is one such solution. The windowed Fourier transform is defined as follows:

$$F_w(\omega,\tau)=\int_{-\infty}^{+\infty}\omega(t-\tau)e^{-j2\pi\omega t}f(t)\,dt \qquad \text{(equ. 2)}$$

Where f(t) is the time domain signal under analysis,

$F_w(\omega,\tau)$ is the windowed Fourier transform of the time domain signal under analysis, and w(t) is the windowing function. The windowing function is usually chosen to be zero outside an interval of finite length. Alternatively, as the spectral content of the input f(t) varies with time, the input signal can be examined by performing the transform at time τ using a more local window function. In either case, the output transform is the convolution of the window function and the signal under analysis so that the spectra of the window itself is present in the transform results. Consequently, the windowing function is chosen to minimize this effect. Looking at this technique from another viewpoint, the basis functions of a windowed Fourier transform are not complex sinusoids but rather are windowed complex sinusoids. Dennis Gabor used a real Gaussian function in conjunction with sinusoids of varying frequencies to produce a complete set of basis functions (known as Gabor functions) with which to analyze a signal. For a locality given by the effective width of the Gaussian function, the sinusoidal frequency is varied such that the entire spectrum is covered.

The wavelet transform decomposes a signal into a set of basis functions that can be nearly local in both frequency and time. This is achieved by translating and dilating a function $\Psi(t)$ that has spatial and spectral locality to form a set of basis functions:

$$\sqrt{s}\psi(s(t-u)) \qquad \text{(equ. 3)}$$

wherein s and u are real numbers and are the variables of the transform. The function $\Psi(t)$ is called the wavelet.

The continuous wavelet transform of a signal under analysis is defined as follows:

$$W(s,u)=\sqrt{s}\int_{-\infty}^{+\infty}\psi\,(s(t-u))\,f(t)\,dt \qquad \text{(equ. 4)}$$

Where f(t) is the time domain signal under analysis,

W(s,u) is its wavelet transform, Ψ is the wavelet, s is the positive dilation factor and u is the scaled translation distance. The spatial and spectral locality of the wavelet transform is dependent on the characteristics of the wavelet.

Because the signal under analysis in the compression of digitally sampled images has finite length, the discrete counterpart of the continuous wavelet transform is used. The wavelet transform performs a multiresolution decomposition based on a sequence of resolutions often referred to as "octaves". The frequencies of consecutive octaves vary uniformly on a logarithmic frequency scale. This logarithmic scale can be selected so that consecutive octaves differ by a factor of two in frequency. The basis functions are:

$$\{\psi^j(x-2^{-j}n)\} \text{ for } (j,n) \in Z^2 \qquad \text{(equ. 5)}$$

where Z is the set of all integers, $Z^2 = \{(j,n) : j,n \in Z\}$, and $\psi^j(x) = \sqrt{2^j}\,\psi(2^j x)$.

In a sampled system, a resolution r signifies that the signal under analysis has been sampled at r samples per unit length. A multiresolution analysis studies an input signal at a number of resolutions, which in the case of the present invention is the sequence $r = 2^j$ where $j \in Z$. The difference in frequency between consecutive octaves therefore varies by a factor of two.

Stephane Mallat formalized the relationship between wavelet transforms and multiresolution analysis by first defining a multiresolution space sequence $\{V_j\}_{j\in Z}$, where V_j is the set of all possible approximated signals at resolution 2^j. He then showed that an orthonormal basis for V_j can be constructed by $\{\phi^j(x-2^{-j}n)\}_{n\in Z}$. $\phi(x)$ is called the scaling function where for any $j \in Z$, $\phi^j(x) = \sqrt{2^j}\,\phi(2^j x)$. He then showed that a signal f(x) can be approximated at a resolution 2^j by the set of samples:

$$S_j = \{\sqrt{2^j}\langle f, \phi_n^j\rangle\}_{n\epsilon z} \qquad \text{(equ. 6)}$$

where $\langle f,g\rangle = \int_{-\infty}^{\infty} f(x)\,g(x)\,dx,$ where $f, g \epsilon L^2(R)$, the set of square integrable functions on R. This is equivalent to convolving the signal f(x) with the scaling function $\phi^j(-x)$ at a sampling rate of 2^j. However, this representation is highly redundant because $V_j \subset V_{j+1}, j\epsilon Z$. It would be more efficient to generate a sequence of multiresolution detail signals O_j which represents the difference information between successive resolutions $O_j \oplus V_j = V_{j+1}$ where O_j is orthogonal to V_j. Mallat proved that there exists a function $\Psi(x)$ called the wavelet where:

$$\psi^j(x) = \sqrt{2^j}\psi(2^j x) \qquad \text{(equ. 7)}$$

such that $\{\Psi^j(x-2^{-j}n)\}_{n\epsilon Z}$ is an orthonormal basis of O_j and $\{\Psi^j(x-2^{-j}n)\}$, $(j,n)\epsilon Z^2$, is an orthonormal basis of $L^2(R)$. The detail signal at resolution 2^{j+1} is represented by the set of data values:

$$N_j = \{\sqrt{2^j}\langle f, \psi_n^j\rangle\}_{n\epsilon z} \qquad \text{(equ. 8)}$$

which is equivalent to convolving the signal f(x) with the wavelet $\Psi^j(-x)$ at a sampling rate of 2^j.

Hence, the original signal f(x) can be completely represented by the sets of data values $(S_J, (N_j) J \leq j \leq -1)$, where J<O gives the number of octaves. This representation in the form of data values is known as the discrete wavelet decomposition. The S_J notation used by Mallat refers to recursively low pass filter values of the original signal. S_0 corresponds to the original data values D. S_{-1} corresponds to the H data values from the low pass filter. N_{-1} corresponds to the G data values from the high pass filter. S_{-2} corresponds to the next low pass filtered values from the previous H sub-band. N_{-2} corresponds to the next high pass filtered values from the previous H sub-band.

If the sampling patterns of the discrete windowed

Fourier transform and the discrete wavelet transform are compared while maintaining the spatial locality of the highest frequency sample for both transforms, then the efficiency of the discrete wavelet decomposition is revealed. The window Fourier transform produces a linear sampling grid, each data value being a constant spatial distance or a constant frequency away from its neighbor. The result is a heavy over-sampling of the lower frequencies. The wavelet transform, in contrast, samples each of its octave wide frequency bands at the minimum rate such that no redundant information is introduced into the discrete wavelet decomposition. The wavelet transform is able to achieve highly local spatial sampling at high frequencies by the use of octave wide frequency bands. At low frequencies, spectral locality takes precedence over spatial locality.

Figure 7 illustrates the spatial and spectral locality of a sequence of sampled data values. The box surrounding a data value represents the spatial and spectral locality of the data value. The regions of Figure 7 are presented for explanation purposes. In reality there is some overlap and aliasing between adjacent data values, the characteristics of which are determined by the particular wavelet function used.

Mallat showed the wavelet transform can be computed with a pyramid technique, where only two filters are used. Using this technique, S_j and N_j are calculated from S_{j+1}, S_j being used as the input for the next octave of decomposition. A low pass filter H:

$$h(n) = \frac{1}{\sqrt{2}}\langle \phi_0^{-1}, \phi_n^0 \rangle \qquad \text{(equ. 9)}$$

Mallat showed that S_j can be calculated by convolving from S_{j+1} with H and keeping every other output (i.e. sub-sampling by a factor of 2).

A method for calculating N_j from S_{j+1} can also be derived. This method involves convolving S_{j+1} with a high

pass filter G and sub-sampling by a factor of 2. The high pass filter G is defined by the following coefficients:

$$g(n) = (-1)^{1-n} h(1-n) \qquad \text{(equ. 10)}$$

The relationship between the H and G filters results in a large saving when the filters are implemented in hardware.

Figures 8 and 9 illustrate that these two filters H and G form a complementary pair that split an input signal into two half band output signals. Both the high and the low pass outputs can be sub-sampled by a factor of two without corrupting the high frequency information because any aliasing introduced by the sub-sampling will be corrected in the reconstruction. There are the same number of filtered data values as there are original image data values.

The particular wavelet which is best in analyzing a signal under analysis is heavily dependent on the characteristics of the signal under analysis. The closer the wavelet resembles the features of the signal, the more efficient the wavelet representation of the signal will be. In addition, reconstruction errors introduced by quantization resemble the wavelet. Typically, the amount of aliasing varies with spatial support (the number of coefficients of the wavelet filters). Long wavelets can be constructed such that aliasing between adjacent octave bands is minimized. However, the spatial equivalent of aliasing, overlap, increases with filter length. Conversely, short wavelets have little or no overlap spatially but exhibit large amounts of aliasing in the frequency domain. To properly determine the suitability of a wavelet for a particular application, these factors of size and shape must be considered.

To apply the wavelet transform to image processing, the present invention employs a particular wavelet called the four coefficient Daubechies wavelet. Because the four

coefficient Daubechies wavelet has only four coefficients, it is very short. This is well-suited for analyzing important image features such as object edges. Edges by definition are spatially local discontinuities. Edges often consist of a wide spectral range which, when filtered through a high pass filter, give rise to relatively larger filtered outputs only when the analysis filter coincides with the edge. When the analysis filter does not coincide with the edge, relatively smaller filtered outputs are output by the filter. The shorter the analysis filter used, the more finely the spatial position of the edge is resolved. Longer filters produce more of the relatively larger data values to represent an edge. The shortness of the filter also makes the transform calculation relatively inexpensive to implement compared with that of longer filters or image transformations such as the Fourier or discrete cosine transforms. The four coefficient Daubechies wavelet was selected for use only after a careful analysis of both its spatial and aliasing characteristics. Longer wavelets such as the six coefficient Daubechies wavelet could, however, also be used if a more complex implementation were acceptable. Short filters such as the two coefficients Haar wavelet could also be used if the attendant high levels of noise were acceptable.

The true coefficients of the four coefficient Daubechies wavelet are:

$$a = \frac{1+\sqrt{3}}{8},\ b=\frac{3+\sqrt{3}}{8},\ c=\frac{3-\sqrt{3}}{8},\ d = \frac{-1+\sqrt{3}}{8} \qquad \text{(equ. 11)}$$

The low pass four coefficient Daubechies digital filter is given by:

$$H\left(\frac{x}{2}\right) = aD(x-1) + bD(x) + cD(x+1) - dD(x+2) \qquad \text{(equ. 12)}$$

The high pass four coefficient Daubechies digital filter is given by:

$$G\left(\frac{x}{2}\right) = dD(x-1) + cD(x) - bD(x+1) + aD(x+2) \qquad \text{(equ. 13)}$$

In equations 12 and 13, D(x-1), D(x), D(x+1) and D(x+2) are four consecutive data values. $H\left(\frac{x}{2}\right)$ and $G\left(\frac{x}{2}\right)$ are true perfect reconstruction filters, i.e. the inverse transform perfectly reconstructs the original data. For example, when the filters operate on data values D(1), D(2), D(3) and D(4), outputs H(1) and G(1) are generated. Index x in this case would be 2. Due to the presence of the $\frac{x}{2}$ as the index for the filters H and G, the values of x can only be even integers.

To simplify the computational complexity involved in performing the transformation on real data, the coefficients of the four coefficient Daubechies filter which are non-rational numbers are converted into rational numbers which can be efficiently implemented in software or hardware. Floating point coefficients are not used because performing floating point arithmetic is time consuming and expensive when implemented in software or hardware.

To convert the four Daubechies coefficients for implementation, three relationships of the coefficients a, b, c and d are important. In order for the H filter to have unity gain, the following equation must hold:

$$a + b + c - d = 1 \qquad \text{(equ. 14)}$$

In order for the G filter to reject all zero frequency components in the input data values, the following equation must hold:

$$a - b + c + d = 0 \qquad \text{(equ. 15)}$$

In order for the resulting H and G filters to be able to generate a decomposition which is perfectly reconstructible into the original image data the following equation must hold:

$$ac - bd = 0 \qquad \text{(equ. 16)}$$

True four coefficient Daubechies filters satisfy the above three equations 14, 15, and 16. However, when the coefficients of the true low and high pass four coefficient Daubechies filters are converted for implementation, at least one of the three relationships must be broken. In the preferred embodiment, unity gain and the rejection of all zero frequency components are maintained. It is the third relationship of equation 16 that is compromised. Perfect reconstruction is compromised because the process of compressing image data itself inherently introduces some noise due to the tree coding and quantization of the present invention. The reconstructed data values therefore necessarily involve noise when a real-world image is compressed and then reconstructed. We define filters which satisfy equations 14, and 15 and approximately satisfy equation 16, quasi-perfect reconstruction filters.

Table 2 illustrates a process of converting the coefficients a, b, c and d for implementation.

$$a = \frac{1+\sqrt{3}}{8} \approx .3415(32) = 10.92 \approx \frac{11}{32}$$

$$b = \frac{3+\sqrt{3}}{8} \approx .5915(32) = 18.92 \approx \frac{19}{32}$$

$$c = \frac{3-\sqrt{3}}{8} = .1585(32) = 5.072 \approx \frac{5}{32}$$

$$d = \frac{-1+\sqrt{3}}{8} \approx .0915(32) = 2.928 \approx \frac{3}{32}$$

Table 2

The true four coefficient Daubechies filter coefficients are listed in the left hand column of Table 2. In the next column to the right, the true coefficients are shown rounded to four places beyond the decimal point. The

rounded coefficients are scaled by a factor of 32 to achieve the values in the next column to the right. From each value in the third column, an integer value is selected. Which integers are selected has a dramatic effect on the complexity of the software or hardware which compresses the image data. The selected integers are divided by 32 so that the scaling by 32 shown in the second column does not change the values of the resulting converted coefficients.

In selecting the integers for the fourth column, the relationship of the three equations 14, 15 and 16 are observed. In the case of $a = 11/32$, $b = 19/32$, $c = 5/32$ and $d = 3/32$, the relationships $a+b+c-d=1$ and $a-b+c+d=0$ both are maintained. Because the converted coefficients in the rightmost column of Table 2 are quite close to the true coefficient values in the leftmost column, the resulting four coefficient filters based on coefficients a, b, c and d allow near perfect reconstruction. On a typical 640 by 480 image, the error between the original and reconstructed data values after forward and then inverse transformation has been experimentally verified to exceed 50 dB.

The resulting high pass four coefficient quasi-Daubechies filter is:

$$H(\tfrac{x}{2}) = \tfrac{11}{32}D(x-1) + \tfrac{19}{32}D(x) + \tfrac{5}{32}D(x+1) - \tfrac{3}{32}D(x+2) \quad \text{(equ. 17)}$$

The resulting low pass four coefficient quasi-Daubechies filter is:

$$G(\tfrac{x}{2}) = \tfrac{3}{32}D(x-1) + \tfrac{5}{32}D(x) - \tfrac{19}{32}D(x+1) + \tfrac{11}{32}D(x+2) \quad \text{(equ. 18)}$$

Because the high and low pass four coefficient quasi-Daubechies filters satisfy equations 14 and 15 and approximately satisfy equation 16, the high and low pass four coefficient quasi-Daubechies filters are quasi-perfect reconstruction filters.

Note that the particular converted coefficients of the quasi-Daubechies filters of equations 17 and 18 result in significant computational simplicity when implementation is either software and/or hardware. Multiplications and divisions by factors of two such as multiplications and divisions by 32 are relatively simple to perform. In either hardware or software, a multiplication by 2 or a division by 2 can be realized by a shift. Because the data values being operated on by the digital filter already exist in storage when the filter is implemented in a typical system, the shifting of this data after the data has been read from storage requires little additional computational overhead. Similarly, changing the sign of a quantity involves little additional overhead. In contrast, multiplication and division by numbers that are not a power of 2 require significant overhead to implement in both software and hardware. The selection of the coefficients in equations 17 and 18 allows H(x) and G(x) to be calculated with only additions and shifts. In other words, all multiplications and divisions are performed without multiplying or dividing by a number which is not a power of 2. Due to the digital filter sequencing through the data values, pipelining techniques can also be employed to reduce the number of adds further by using the sums or differences computed when the filters were operating on prior data values.

Moreover, the magnitudes of the inverse transform filter coefficients are the same as those of the transform filter itself. As described further below, only the order and signs of the coefficients are changed. This reduces the effective number of multiplications which must be performed by a factor of two when the same hardware or software implementation is to be used for both the forward and inverse transform. The fact that the signal being analyzed is being sub-sampled reduces the number of additions by a factor of two because summations are required only on the reading of every other sample. The

effective number of filters is therefore only one to both transform the data into the decomposition and to inverse transform the decomposition back into the image data.

IMAGE COMPRESSION AND DECOMPRESSION USING THE QUASI-PERFECT RECONSTRUCTION TRANSFORM

Color images can be decomposed by treating each Red-Green-Blue (or more usually each Luminance-Chrominance-Chrominance channel) as a separate image. In the case of Luminance-Chrominance-Chrominance (YUV or YIQ) images the chrominance components may already have been sub-sampled. It may be desirable therefore, to transform the chrominance channels through a different number of octaves than the luminance channel. The eye is less sensitive to chrominance at high spatial frequency and therefore these channels can be sub-sampled without loss of perceived quality in the output image. Typically these chrominance channels are sub-sampled by a factor of two in each dimension so that they together take only 50 percent of the bandwidth of the luminance channel. When implementing an image compression technique, the chrominance channels are usually treated the same way as the luminance channel. The compression technique is applied to the three channels independently. This approach is reasonable except in the special cases where very high compression ratios and very high quality output are required. To squeeze the last remaining bits from a compression technique or to achieve more exacting quality criteria, knowledge of how the chrominance rather than luminance values are perceived by the human visual system can be applied to improve the performance of the compression technique by better matching it with the human visual system.

Figure 10 is an illustration of a two dimensional matrix of data values. There are rows of data values extending in the horizontal dimension and there are columns of data values extending in the vertical dimension. Each of the data values may, for example, be

an 8-bit binary number of image pixel information such as the luminance value of a pixel. The data values of Figure 10 represent an image of a black box 100 on a white background 101.

To transform the data values of the image of Figure 10 in accordance with one aspect of the present invention, a high pass four coefficient quasi-Daubechies digital filter is run across the data values horizontally, row by row, to result in a block 102 of high pass output values G shown in Figure 11. The width of the block 102 of high pass output values in Figure 11 is half the width of the original matrix of data values in Figure 10 because the high pass four coefficient quasi-Daubechies digital filter is moved across the rows of the data values by twos. Because only one additional digital filter output is generated for each additional two data values processed by the digital filter, the data values of Figure 10 are said to have been sub-sampled by a factor of two.

Figure 12 illustrates the sub-sampling performed by the high pass digital filter. High pass output G_1 is generated by the high pass digital filter from data values D_1, D_2, D_3 and D_4. The next high pass output generated, output G_2, is generated by the high pass digital filter from data values D_3, D_4, D_5 and D_6. The high pass digital filter therefore moves two data values to the right for each additional high pass output generated.

A low pass four coefficient quasi-Daubechies digital filter is also run across the data values horizontally, row by row, to generate H block 103 of the low pass outputs shown in Figure 11. This block 103 is generated by sub-sampling the data values of Figure 10 in the same way the block 102 was generated. The H and G notation for the low and high pass filter outputs respectively is used as opposed to the S_j and O_j notation used by Mallat to simplify the description of the two-dimensional wavelet transform.

Figure 13 illustrates the sub-sampling of the low

pass digital filter. Low pass output H_1 is generated by the low pass digital filter from data values D_1, D_2, D_3 and D_4. The next low pass output generated, output H_2, is generated by the low pass digital filter from data values D_3, D_4, D_5 and D_6. The low pass digital filter therefore moves two data values to the right for each additional low pass output generated.

After the high and low pass four coefficient quasi-Daubechies digital filters have generated blocks 102 and 103, the high and low pass four coefficient quasi-Daubechies digital filters are run down the columns of blocks 102 and 103. The values in blocks 102 and 103 are therefore sub-sampled again. The high pass four coefficient quasi-Daubechies digital filter generates blocks 104 and 105. The low pass four coefficient quasi-Daubechies digital filter generates blocks 106 and 107. The resulting four blocks 104-107 are shown in Figure 14. Block 106 is the low frequency component of the original image data. Blocks 107, 104 and 105 comprise the high frequency component of the original image data. Block 106 is denoted block HH. Block 107 is denoted block GH. Block 104 is denoted block HG. Block 105 is denoted block GG.

This process of running the high and low pass four coefficient quasi-Daubechies digital filters across data values both horizontally and vertically to decompose data values into high and low frequency components is then repeated using the data values of the HH block 106 as input data values. The result is shown in Figure 15. Block 108 is the low frequency component and is denoted block HHHH. Blocks 109, 110 and 111 comprise octave 1 of the high frequency component and are denoted HHHG, HHGH, HHGG, respectively. Blocks HG, GH and GG comprise octave 0 of the high frequency component.

Although this recursive decomposition process is only repeated twice to produce high pass component octaves 0 and 1 in the example illustrated in connection with

Figures 10-15, other numbers of recursive decomposition steps are possible. Recursively decomposing the original data values into octaves 0, 1, 2 and 3 has been found to result in satisfactory results for most still image data and recursively decomposing the original data into octaves 0, 1, and 2 has been found to result in satisfactory results for most video image data.

Moreover, the horizontal and subsequent vertical operation of the high and low pass filters can also be reversed. The horizontal and subsequent vertical sequence is explained in connection with this example merely for instructional purposes. The filters can be moved in the vertical direction and then in the horizontal direction. Alternatively, other sequences and dimensions of moving the digital filters through the data values to be processed is possible.

It is also to be understood that if the original image data values are initially arrayed in a two dimensional block as shown in Figure 10, then the processing of the original image data values by the high and low pass filters would not necessarily result in the HH values being located all in an upper right hand quadrant as is shown in Figure 14. To the contrary, depending on where the generated HH values are written, the HH data values can be spread throughout a block. The locations of the HH values are, however, determinable. The HH values are merely illustrated in Figure 14 as being located all in the upper lefthand quadrant for ease of illustration and explanation.

Figure 16 is an illustration showing one possible twelve-by-twelve organization of original image data values in a two dimensional array. Figure 16 corresponds with Figure 10. The location in the array of each data value is determined by a row number and column number. A row number and column number of a data value may, for example, correspond with a row address and column address in an addressed storage medium. This addressed storage

medium may, for example, be a semiconductor memory, a magnetic storage medium, or an optical storage medium. The row and column may, for example, also correspond with a pixel location including a location of a pixel on a cathode-ray tube or on a flat panel display.

Figure 17 is an illustration showing the state of the two dimensional array after a one octave decomposition. The HH low frequency components are dispersed throughout the two dimensional array as are the HG values, the GH values, and the GG values. The subscripts attached to the various data values in Figure 17 denote the row and column location of the particular data value as represented in the arrangement illustrated in Figure 14. HH_{00}, HH_{01}, HH_{02}, HH_{03}, HH_{04} and HH_{05}, for example, are six data values which correspond with the top row of data values in HH block 106 of Figure 14. HH_{00}, HH_{10}, HH_{20}, HH_{30}, HH_{40} and HH_{50}, for example, are six data values which correspond with the leftmost column of data values in HH block 106 of Figure 14.

When the high and the low pass forward transform digital filters operate on the four data values D_{01}, D_{02}, D_{03} and D_{04} of Figure 16, the output of the low pass forward transform digital filter is written to location row 0 column 2 and the output of the high pass forward transform digital filter is written to location row 0 column 3. Next, the high and low pass forward transform digital filters are moved two locations to the right to operate on the data values D_{03}, D_{04}, D_{05} and D_{06}. The outputs of the low and high pass forward transform digital filters are written to locations row 0 column 4 and row 0 column 5, respectively. Accordingly, the outputs of the low and high frequency forward transform digital filters are output from the filters to form an interleaved sequence of low and high frequency component data values which overwrite the rows of data values in the two dimensional array.

Similarly, when the low and high pass forward

transform digital filters operate on the four data values at locations column 0, rows 1 through 4, the output of the low pass forward transform digital filter is written to location column 0 row 2. The output of the high pass forward transform digital filter is written to location column 0 row 3. Next the low and high pass forward transform digital filters are moved two locations downward to operate on the data values at locations column 0, rows 3 through 6. The outputs of the low and high pass forward transform digital filters are written to locations column 0 row 4 and column 0 row 5, respectively. Again, the outputs of the low and high pass forward transform digital filters are output from the filters in an interleaved fashion to overwrite the columns of the two dimensional array.

Figure 18 is an illustration showing the state of the two dimensional array after a second octave decomposition. The HHHH low frequency components corresponding which block 108 of Figure 15 as well as the octave 1 high frequency components HHGH, HHHG and HHGG are dispersed throughout the two dimensional array. When the HH values HH_{01}, HH_{02}, HH_{03} and HH_{04} of Figure 17 are processed by the low and high pass forward transform digital filters, the outputs are written to locations row 0 column 4 and row 0 column 6, respectively. Similarly, when the values at locations column 0, rows 2, 4, 6 and 8 are processed by the low and high pass forward transform digital filters, the results are written to locations column 0 row 4 and column 0 row 6, respectively. The data values in Figure 18 are referred to as transformed data values. The transformed data values are said to comprise the decomposition of the original image values.

This method of reading data values, transforming the data values, and writing back the output of the filters is easily expanded to a two dimensional array of a very large size. Only a relatively small number of locations is shown in the two dimensional array of Figures 10-18 for

ease of explanation and clarity of illustration.

The transformed data values are reconverted back into image data values substantially equal to the original image data by carrying out a reverse process. This reverse process is called the inverse transform. Due to the interleaved nature of the decomposition data in Figure 18, the two digital filters used to perform the inverse transform are called interleaved inverse transform digital filters. Odd data values are determined by an odd interleaved inverse digital filter O. Even data values are determined by the even interleaved inverse transform digital filter E.

The odd and even interleaved inverse digital filters can be determined from the low and high pass forward transform digital filters used in the forward transform because the coefficients of the odd interleaved inverse transform digital filters are related to the coefficients of the low and high pass forward transform filters. To determine the coefficients of the odd and even interleaved inverse transform digital filters, the coefficients of the low and high pass forward transform digital filters are reversed. Where the first, second, third and fourth coefficients of the low pass forward transform digital filter H of equation 17 are denoted a, b, c and -d, the first, second, third and fourth coefficients of a reversed filter H* are denoted -d, c, b and a. Similarly, where the first, second, third and fourth coefficients of the high pass forward transform digital filter G of equation 18 are denoted d, c, -b and a, the first, second, third and fourth coefficients of a reverse filter G* are denoted a, -b, c and d.

The first through the fourth coefficients of the even interleaved inverse transform digital filter E are the first coefficient of H*, the first coefficient of G*, the third coefficient of H*, and the third coefficient of G*. The coefficients of the even interleaved inverse transform digital filter E therefore are -d, a, b and c. In the

case of the low and high pass four coefficient quasi-Daubechies filters used in the transform where $a=\frac{11}{32}$, $b=\frac{19}{32}$, $c=\frac{5}{32}$ and $d=\frac{3}{32}$, the even interleaved inverse transform digital filter is:

$$\frac{D(2x)}{2} = -\tfrac{3}{32}H(x-1) + \tfrac{11}{32}G(x-1) + \tfrac{19}{32}H(x) + \tfrac{5}{32}G(x) \quad \text{(equ. 19)}$$

where H(x-1), G(x-1), H(x) and G(x) are transformed data values of a decomposition to be inverse transformed.

The first through the fourth coefficients of the odd interleaved inverse transform digital filter O are the second coefficient of H*, the second coefficient of G*, the fourth coefficient of H*, and the fourth coefficient of G*. The coefficients of the odd interleaved inverse transform digital filter O therefore are c, -b, a and d. In the case of the low and high pass four coefficient quasi-Daubechies filters used in the transform where $a=\frac{11}{32}$, $b=\frac{19}{32}$, $c=\frac{5}{32}$ and $d=\frac{3}{32}$, the odd interleaved inverse transform digital filter is:

$$\frac{D(2x-1)}{2} = \tfrac{5}{32}H(x-1) - \tfrac{19}{32}G(x-1) + \tfrac{11}{32}H(x) + \tfrac{3}{32}G(x) \quad \text{(equ. 20)}$$

where H(x-1), G(x-1), H(x) and G(x) are data values of a decomposition to be inverse transformed.

To inverse transform the transformed data values of Figure 18 into the data values of Figure 17, the HHHG, HHGG, HHGH and data values are inverse transformed with the HHHH data values to create the HH data values of Figure 17. This process corresponds with the inverse transformation of HHHG block 109, HHGH block 110, HHGG block 111, and HHHH block 108 of Figure 15 back into the HH data values of block 106 of Figure 14. The HG, GH and GG data values of Figure 18 are therefore not processed by the odd and even interleaved inverse transform digital filters in this step of the inverse transform.

In Figure 18, the odd interleaved inverse transform digital filter processes the values in locations column 0, rows 0, 2, 4 and 6 to generate the odd data value at location column 0 row 2. The even interleaved inverse transform digital filter data also processes the values in the same locations to generate the even data value at location column 0 row 4. The odd and even interleaved inverse transform digital filters then process the values in locations column 0, rows 4, 6, 8 and A to generate the values at locations column 0 row 6 and column 0 row 8, respectively. Each of the six columns 0, 2, 6, 4, 8, and A of the values of Figure 18 are processed by the odd and even interleaved inverse transform digital filters in accordance with this process.

The various locations are then processed again by the odd and even interleaved inverse transform digital filters, this time in the horizontal direction. The odd and even interleaved inverse transform digital filters process the values at locations row 0 columns 0, 2, 4 and 6 to generate the values at locations row 0 column 2 and row 0 column 4, respectively. The odd and even interleaved inverse transform digital digital filters process the values at locations row 0 columns 4, 6, 8 and A to generate the values at locations row 0 column 6 and row 0 column 8, respectively. Each of the six rows 0, 2, 4 and 8 and of values are processed by the even and odd interleaved inverse transform digital filters in accordance with this process. The result is the reconstruction shown in Figure 17.

The even and odd interleaved inverse transform digital filters then process the values shown in Figure 17 into the data values shown in Figure 16. This inverse transformation corresponds with the transformation of the HH block 106, the HG bock 104, the GH block 107 and the GG block 105 of Figure 14 into the single block of data value of Figure 10. The resulting reconstructed data values of Figure 16 are substantially equal to the original image

data values.

Note, however, that in the forward transform of the data values of Figure 16 into the data values of Figure 17 that the low and high pass four coefficient quasi-Daubechies digital filters cannot generate all the data values of Figure 17 due to the digital filters requiring data values which are not in the twelve by twelve matrix of data values of Figure 16. These additional data values are said to be beyond the "boundary" of the data values to be transformed.

Figure 19 illustrates the high pass four coefficient quasi-Daubechies digital filter operating over the boundary to generate the G_0 data value. In order to generate the G_0 data value in the same fashion that the other high frequency G data values are generated, the high pass digital filter would require data values D_{-1}, D_0, D_1 and D_2 as inputs. Data value D_{-1}, however, does not exist. Similarly, Figure 20 illustrates the low pass four coefficient quasi-Daubechies digital filter operating over the boundary to generate the H_0 data value. In order to generate the H_0 data value in the same fashion that the other low frequency H data values are generated, the low pass digital filter would require data values D_{-1}, D_0, D_1 and D_2 as inputs. Data value D_{-1}, however, does not exist.

The present invention solves this boundary problem by using additional quasi-Daubechies digital filters to generate the data values adjacent the boundary that would otherwise require the use of data values outside the boundary. There is a high pass "start" quasi-Daubechies forward transform digital filter G_s which is used to generate the first high pass output G_0. There is a low pass "start" quasi-Daubechies forward transform digital filter H_s which is used to generate the first low pass output H_0. These start quasi-Daubechies forward transform digital filters are three coefficient filters rather than four coefficient filters and therefore require only three data values in order to generate an output. This allows

the start quasi-Daubechies forward transform digital filters to operate at the boundary and to generate the first forward transform data values without extending over the boundary.

Figure 21 illustrates the low and high pass start quasi-Daubechies forward transform digital filters operating at the starting boundary of image data values D_0 through D_B. The three coefficient low and high pass start quasi-Daubechies forward transform digital filters operate on data values D_0, D_1 and D_2 to generate outputs H_0 and G_0, respectively. H_1, H_2, H_3 and H_4, on the other hand, are generated by the low pass four coefficient quasi-Daubechies forward transform digital filter and G_1, G_2, G_3 and G_4 are generated by the high pass four coefficient quasi-Daubechies forward transform digital filter.

A similar boundary problem is encountered at the end of the data values such as at the end of the data values of a row or a column of a two-dimensional array. If the low and high pass four coefficient quasi-Daubechies filters G and H are used at the boundary in the same fashion that they are in the middle of the data values, then the four coefficient quasi-Daubechies forward transform digital filters would have to extend over the end boundary to generate the last low and high pass outputs, respectively.

The present invention solves this boundary problem by using additional quasi-Daubechies forward transform digital filters in order to generate the transformed data values adjacent the end boundary that would otherwise require the use of data outside the boundary. There is a low pass "end" quasi-Daubechies forward transform digital filter H_e which is used to generate the last low pass output. There is a high pass "end" quasi-Daubechies forward transform digital filter G_e which is used to generate the last high pass output. These two end quasi-Daubechies forward transform digital filters are three coefficient filters rather than four coefficient filters

and therefore require only three data values in order to generate an output. This allows the end quasi-Daubechies forward transform digital filters to operate at the boundary and to generate the last transform data values without extending over the boundary.

Figure 21 illustrates two low and high pass end quasi-Daubechies forward transform digital filters operating at the end boundary of the image data. These three coefficient low and high pass end quasi-Daubechies forward transform digital filters operate on data values D_9, D_A and D_B to generate outputs H_5 and G_5, respectively. This process of using the appropriate start or end low or high pass filter is used in performing the transformation at the beginning and at the end of each row and column of the data values to be transformed.

The form of the low pass start quasi-Daubechies forward transform digital filter H_s is determined by selecting a value of a hypothetical data value D_{-1} which would be outside the boundary and then determining the value of the four coefficient low pass quasi-Daubechies forward transform filter if that four coefficient forward transform filter were to extend beyond the boundary to the hypothetical data value in such a way as would be necessary to generate the first low pass output H_0. This hypothetical data value D_{-1} outside the boundary can be chosen to have one of multiple different values. In some embodiments, the hypothetical data value D_{-1} has a value equal to the data value D_0 at the boundary. In some embodiments, the hypothetical data value D_{-1} is set to zero regardless of the data value D_0. The three coefficient low pass start quasi-Daubechies forward transform digital filter H_s therefore has the form:

$$H_0 = K1 + bD_0 + cD_1 - dD_2 \qquad \text{(equ. 21)}$$

where K1 is equal to the product aD_{-1}, where D_0 is the first data value at the start boundary at the start of a

sequence of data values, and where a, b, c and d are the four coefficients of the four coefficient low pass quasi-Daubechies forward transform digital filter. If, for example, hypothetical data value D_{-1} is chosen to be equal to the data value D_0 adjacent but within the boundary, then $K1=aD_0$ where a = 11/32 and D_0 is the data value adjacent the boundary, equation 21 then becomes:

$$H_0 = (a+b)D_0 + cD_1 - dD_2 \qquad \text{(equ. 22)}$$

The form of the high pass start quasi-Daubechies forward transform digital filter G_s is determined by the same process using the same hypothetical data value D_{-1}. The high pass start quasi-Daubechies forward transform digital filter G_s therefore has the form:

$$G_0 = K2 + cD_0 - bD_1 + aD_2 \qquad \text{(equ. 23)}$$

where K2 is equal to the product dD_{-1}, where D_0 is the first data value at the boundary at the start of a sequence of data values, and where a, b, c and d are the four coefficients of the four coefficient high pass quasi-Daubechies forward transform digital filter. If hypothetical data value D_{-1} is chosen to be equal to D_0, then equation 23 becomes:

$$G_0 = (d + c)D_0 - bD_1 + aD_2 \qquad \text{(equ. 24)}$$

The form of the low pass end quasi-Daubechies forward transform digital filter H_e is determined in a similar way to the way the low pass start quasi-Daubechies forward transform digital filter is determined. A value of a data value D_C is selected which would be outside the boundary. The value of the four coefficient low pass quasi-Daubechies forward transform digital filter is then determined as if that four coefficient filter were to extend beyond the boundary to data value D_C in such a way

as to generate the last low pass output H_5. The three coefficient low pass end quasi-Daubechies forward transform digital filter therefore has the form:

$$H_5 = aD_9 + bD_A + cD_B - K3 \qquad \text{(equ. 25)}$$

where K3 is equal to the product dD_C, where D_B is the last data value of a sequence of data values to be transformed, and where a, b, c and d are the four coefficients of the four coefficient low pass quasi-Daubechies filter. D_B is the last data value in the particular sequence of data values of this example and is adjacent the end boundary. In the case where the hypothetical data value D_c is chosen to be equal to the data value D_B adjacent but within the end boundary, then $K3=dD_B$ and equation 25 becomes:

$$H_5 = aD_9 + bD_A + (c-d)D_B \qquad \text{(equ. 26)}$$

The form of the high pass end quasi-Daubechies forward transform digital filter G_5 is determined by the same process using the same data value D_C. The three coefficient high pass end quasi-Daubechies forward transform digital filter therefore has the form:

$$G_5 = dD_9 + cD_A - bD_B + K4 \qquad \text{(equ. 27)}$$

where K4 is equal to the product aD_C, where D_B is the last data value in this particular sequence of data values to be transformed, and where a, b, c and d are the four coefficients of the four coefficient high pass quasi-Daubechies forward transform digital filter. D_B is adjacent the end boundary. If hypothetical data value D_C is chosen to be equal to D_B, then equation 27 becomes:

$$G_5 = dD_9 + cD_A + (-b+a)D_B \qquad \text{(equ. 28)}$$

It is to be understood that the specific low and high

pass end quasi-Daubechies forward transform digital filters are given above for the case of data values D_0 through D_B of Figure 21 and are presented merely to illustrate one way in which the start and end digital filters may be determined. In the event quasi-Daubechies filters are not used for the low and high pass forward transform digital filters, the same process of selecting a hypothetical data value or values outside the boundary and then determining the value of a filter as if the filter were to extend beyond the boundary can be used. In some embodiments, multiple hypothetical data values may be selected which would all be required by the digital filters operating on the inside area of the data values in order to produce an output at the boundary. This boundary technique is therefore extendable to various types of digital filters and to digital filters having numbers of coefficients other than four.

As revealed by Figure 22, not only does the forward transformation of data values at the boundary involve a boundary problem, but the inverse transformation of the transformed data values back into original image data values also involves a boundary problem. In the present example where four coefficient quasi-Daubechies filters are used to forward transform non-boundary data values, the inverse transform involves an odd inverse transform digital filter as well as an even inverse transform digital filter. Each of the odd and even filters has four coefficients. The even and odd reconstruction filters alternatingly generate a sequence of inverse transformed data values.

In Figure 22, the data values to be transformed are denoted H_0, G_0 ... H_4, G_4, H_5, G_5. Where the forward transform processes the rows first and then the columns, the inverse transform processes the columns first and then the rows. Figure 22 therefore shows a column of transferred data values being processed in a first step of the inverse transform. Both the forward and the inverse

transforms in the described example, however, process the columns in a downward direction and process the rows in a left-right direction.

In Figure 22, the inverse transformed data values reconstructed by the inverse transform digital filters are denoted D_0, D_1, D_2, D_3 ... D_8. The odd inverse transform digital filter outputs are shown on the left and the even inverse transform digital filter outputs are shown on the right.

At the beginning of the sequence of data values H_0, G_0, H_1, G_1 ... H_5 and G_5 to be inverse transformed, the four coefficient odd and even inverse transform digital filters determine the values of reconstructed data values D_1 and D_2 using values H_0, G_0, H_1 and G_1, respectively. Reconstructed data value D_0, however, cannot be reconstructed from the four coefficient even inverse transform digital filter without the four coefficient even inverse transform digital filter extending beyond the boundary. If the four coefficient even inverse transform filter were to be shifted two data values upward so that it could generate data value D_0, then the even four coefficient inverse transform digital filter would require two additional data values to be transformed, data values G_{-1} and H_{-1}. H_0 is, however, the first data value within the boundary and is located adjacent the boundary.

To avoid the even four coefficient inverse transform digital filter extending beyond the boundary, a two coefficient inverse transform digital filter is used:

$$D_0 = 4[(b-a)H_0 + (c-d)G_0] \qquad \text{(equ. 29)}$$

in the case where $K1 = aD_0$ and $K2 = dD_0$. D_0 is the first data value and H_0 is the data value to be inverse transformed adjacent the start boundary. This even start inverse transform digital filter has the form of the four coefficient even inverse transform digital filter except that the G_{-1} data value outside the boundary is chosen to

be equal to H_0, and the H_{-1} data value outside the boundary is chosen to be equal to G_0. The even start invere transform digital filter therefore determines D_0 as a function of only H_0 and G_0 rather than as a function of H_{-1}, G_{-1}, H_0 and G_0.

Similarly, a two coefficient odd end inverse transform digital filter is used to avoid the four coefficient odd inverse transform digital filter from extending beyond the end boundary at the other boundary of a sequence of data values to be inverse transformed. The two coefficient odd end inverse transform digital filter used is:

$$D_B = 4[(c+d)H_5 - (a+b)G_5] \qquad \text{(equ. 30)}$$

in the case where $K4 = aD_B$ and $K3 = dD_B$. D_B is the data value to be determined and G_5 is the data value to be inverse transformed adjacent the end boundary. This odd end inverse transform digital filter has the form of the four coefficient odd inverse transform digital filter except that the H_6 data value outside the boundary is chosen to be equal to G_5 and the G_6 data value outside the boundary is chosen to be equal to H_5. The odd end inverse transform digital filter therefore determines D_B as a function of only H_5 and G_5 rather than as a function of H_5, G_5, H_6 and G_6.

It is to be understood that the particular even start and odd end inverse transform digital filters used in this embodiment are presented for illustrative purposes only. Where there is a different number of data values to be inverse transformed in a sequence of data values, an even end inverse transform digital filter may be used at the boundary rather than the odd end inverse transform digital filter. The even end inverse transform digital filter is an even inverse transform digital filter modified in accordance with the above process to have fewer coefficients than the even inverse transform digital

filter operating on the inner data values. Where filters other than quasi-Daubechies inverse transform digital filters are used, start and end inverse transform digital filters can be generated from the actual even and odd inverse transform digital filters used to inverse transform data values which are not adjacent to a boundary. In the inverse transform, the start inverse transform digital filter processes the start of the transformed data values at the start boundary, then the four coefficient inverse transform digital filters process the non-boundary transformed data values, and then the end inverse transform digital filter processes the end of the transformed data values.

The true Daubechies filter coefficients a, b, c and d fulfil some simple relationships which show that the inverse transform digital filters correctly reconstruct non-boundary original image data values.

$$a+c = \tfrac{1}{2},\ b-d = \tfrac{1}{2},\ c+d = \tfrac{1}{4},\ b-a = \tfrac{1}{4} \qquad \text{(equ. 31)}$$

and the second order equations:

$$ac-bd = 0,\ a^2+b^2+c^2+d^2 = \tfrac{1}{2} \qquad \text{(equ. 32)}$$

Take two consecutive H,G pairs:

$$H\left(\frac{x}{2}\right) = aD(x-1)+bD(x)+cD(x+1)-dD(x+2) \qquad \text{(equ. 33)}$$

$$G\left(\frac{x}{2}\right) = dD(x-1)+cD(x)-bD(x+1)+aD(x+2) \qquad \text{(equ. 34)}$$

$$H\left(\frac{x}{2}+1\right) = aD(x+1)+bD(x+2)+cD(x+3)-dD(x+4) \qquad \text{(equ. 35)}$$

$$G\left(\frac{x}{2}+1\right) = dD(x+1)+cD(x+2)-bD(x+3)+aD(x+4) \qquad \text{(equ. 36)}$$

Multiplying Equations 33 to 36 using the inverse transform digital filters gives:

$$cH\left(\frac{x}{2}\right) = acD(x-1)+bcD(x)+c^2D(x+1)-cdD(x+2) \qquad \text{(equ. 37)}$$

$$-bG\left(\frac{x}{2}\right) = -bdD(x-1)-bcD(x)+b^2D(x+1)-abD(x+2) \qquad \text{(equ. 38)}$$

$$aH\left(\frac{x}{2}+1\right) = a^2D(x+1)+abD(x+2)+acD(x+3)-adD(x+4) \qquad \text{(equ. 39)}$$

$$dG\left(\frac{x}{2}+1\right) = d^2D(x+1)+cdD(x+2)-bdD(x+3)+adD(x+4) \qquad \text{(equ. 40)}$$

$$-dH\left(\frac{x}{2}\right) = -adD(x-1)-bdD(x)-cdD(x+1)+d^2D(x+2) \qquad \text{(equ. 41)}$$

$$aG\left(\frac{x}{2}\right) = adD(x-1)+acD(x)-abD(x+1)+a^2D(x+2) \qquad \text{(equ. 42)}$$

$$bH\left(\frac{x}{2}+1\right) = abD(x+1)+b^2D(x+2)+bcD(x+3)-bdD(x+4) \qquad \text{(equ. 43)}$$

$$cG\left(\frac{x}{2}+1\right) = cdD(x+1)+c^2D(x+2)-bcD(x+3)+acD(x+4) \qquad \text{(equ. 44)}$$

Summing equations 37-40 and 41-44 yields:

$$cH\left(\frac{x}{2}\right) - bG\left(\frac{x}{2}\right) + aH\left(\frac{x}{2}+1\right) + dG\left(\frac{x}{2}+1\right) =$$
$$(ac-bd)D(x-1)+(a^2+b^2+c^2+d^2)D(x+1)+(ac-bd)D(x+3) = D(x+1)/2 \qquad \text{(equ. 45)}$$

$$-dH\left(\frac{x}{2}\right) + aG\left(\frac{x}{2}\right) + bH\left(\frac{x}{2}+1\right) + cG\left(\frac{x}{2}+1\right) =$$
$$(ac-bd)D(x)+(a^2+b^2+c^2+d^2)D(x+2)+(ac-bd)D(x+4) = D(x+2)/2 \qquad \text{(equ. 46)}$$

Using the coefficients of the four coefficient true Daubechies filter, the relationships of equations 31 and 32 hold. Equations 45 and 46 therefore show that with a one bit shift at the output, the original sequence of data values is reconstructed.

Similarly, that the even start reconstruction filter of equation 29 and the odd end reconstruction filter of equation 30 correctly reconstruct the original image data adjacent the boundaries is shown as follows.

For the even start filter, with the choice of $K1 = aD_0$ and $K2 = dD_0$ in equations 29 and 30, we have:

$$H_0 = (a+b)D_0 + cD_1 - dD_2 \quad \text{(equ. 47)}$$

$$G_0 = (c+d)D_0 - bD_1 + aD_2 \quad \text{(equ. 48)}$$

so

$$bH_0 = b(a+b)D_0 + cbD_1 - dbD_2 \quad \text{(equ. 49)}$$

$$cG_0 = c(c+d)D_0 - cbD_1 + acD_2 \quad \text{(equ. 50)}$$

$$aH_0 = a(a+b)D_0 + acD_1 - adD_2 \quad \text{(equ. 51)}$$

$$dG_0 = d(c+d)D_0 - dbD_1 + adD_2 \quad \text{(equ. 51')}$$

and hence: from equation 29:

$$bH_0 + cG_0 - aH_0 - dG_0 = (b^2-a^2+c^2-d^2)D_0 = \frac{D_0}{4} \quad \text{(equ. 52)}$$

For the odd end filter, with the choice of $K_3 = dD_B$ and $K_4 = aD_B$, we have:

$$H_5 = aD_9 + bD_A + (c-d)D_B \quad \text{(equ. 53)}$$

$$G_5 = dD_9 + cD_A + (a-b)D_B \quad \text{(equ. 54)}$$

$$cH_5 = acD_9 + bcD_A + c(c-d)D_B \quad \text{(equ. 55)}$$

$$-bG_5 = -bdD_9 - bcD_A - b(a-b)D_B \quad \text{(equ. 56)}$$

$$dH_5 = daD_9 + bdD_A + d(c-d)D_B \quad \text{(equ. 57)}$$

$$-aG_5 = -adD_9 - caD_A - a(a-b)D_B \quad \text{(equ. 58)}$$

and hence from equation 30:

$$(c+d)H_5 - (a+b)G_5 = (c^2-d^2+b^2-a^2)D_B = \frac{D_B}{4} \quad \text{(equ. 59)}$$

This reveals that the start and end boundary inverse transform digital filters can reconstruct the boundary data values of the original image when low pass and high pass start and end digital filters are used in the forward transform.

TREE ENCODING AND DECODING

As described above, performing the forward quasi-perfect inverse transform does not reduce the number of data values carrying the image information. Accordingly, the decomposed data values are encoded such that not all of the data values need be stored or transmitted. The present invention takes advantage of characteristics of the Human Visual System to encode more visually important information with a relatively larger number of bits while encoding less visually important information with a relatively smaller number of bits.

By applying the forward quasi-perfect inverse transform to a two-dimensional array of image data values, a number of sub-band images of varying dimensions and spectral contents is obtained. If traditional sub-band coding were used, then the sub-band images would be encoded separately without reference to each other except perhaps for a weighting factor for each band. This traditional sub-band encoding method is the most readily-recognized encoding method because only the spectral response is accurately localized in each band.

In accordance with the present invention, however, a finite support wavelet is used in the analysis of an image, so that the sub-bands of the decomposition include spatially local information which indicate the spatial locations in which the frequency band occurs. Whereas most sub-band encoding methods use long filters in order to achieve superior frequency separation and maximal stop band rejection, the filter used in the present invention has compromised frequency characteristics in order to maintain good spatial locality.

Images can be thought of as comprising three components: background intensities, edges and textures. The forward quasi-perfect inverse transform separates the background intensities (the low pass luminance and chrominance bands) from the edge and texture information contained in the high frequency bands. Ideally, enough bandwidth would be available to encode both the edges and the textures so that the image would reconstruct perfectly. The compression due to the encoding would then be entirely due to removal of redundancy within the picture. If, however, the compressed data is to be transmitted and/or stored at low data transmission rates, some visual information of complex images must be lost. Because edges are a visually important image feature, the encoding method of the present invention locates and encodes information about edges or edge-like features for transmission or storage and places less importance on encoding textural information.

There are no exact definitions of what constitutes an edge and what constitutes texture. The present invention uses a definition of an edge that includes many types of textures. An edge or an edge-like feature is defined as a spatially local phenomenon giving rise to a sharp discontinuity in intensity, the edge or edge-like feature having non-zero spectral components over a range of frequencies. Accordingly, the present invention uses a frequency decomposition which incorporates spatial locality and which is invertible. The wavelet transform realized with quasi-perfect inverse transform digital filters meets these requirements.

Because an edge has non-zero components over a range of frequencies of the decomposition in the same locality, an edge can be located by searching through the wavelet decomposition for non-zero data values that represent edges. The method begins searching for edges by examining the low frequency sub-bands of the decomposition. These bands have only a small number of data values because of

the subsampling used in the wavelet transform and because the spatial support of each low frequency data value is large. After a quick search of the lowest frequency sub-bands, the positions of potential edges are determined. Once the locations of the edges are determined in the lowest frequency sub-bands, these locations can be examined at a higher frequency resolutions to confirm that the edges exist and to more accurately determine their spatial locations.

Figure 23 illustrates an example of a one-dimensional binary search. There are three binary trees arranged from left to right in the decomposition of Figure 23. There are three octaves, octaves 0, 1 and 2, of decomposed data values in Figure 23. The low pass component is not considered to be an octave of the decomposition because most of the edge information has been filtered out. Figures 24A-24D illustrate the forward transformation of a one-dimensional sequence of data values D into a sequence of transformed data values such as the tree structure of Figure 23. The data values of the sequence of Figure 24A are filtered into low and high frequency components H and G of Figure 24B. The low frequency component of Figure 24B is then filtered into low and high frequency components HH and HG of Figure 24C. The low frequency component HH of Figure 24C is then filtered into low and high frequency components HHH and HHG. The transformed data values of HHH block 240 of Figure 24D correspond with the low frequency component data values A, G and M of Figure 23. The transformed data values of HHG block 241 of Figure 24D correspond with the octave 2 data values B, H and N of Figure 23. The transformed data values of HG block 242 of Figure 24D correspond with the octave 1 data values of Figure 23. Similarly, the transformed data values of G block 243 correspond with the octave 0 data values of Figure 23. Although only three trees are shown in Figure 23, the number of HHH data values in block 240 can be large and the size of the tree structure of Figure

23 can extend in the horizontal dimension in a corresponding manner.

The encoding of a one dimensional wavelet decomposition such as the decomposition of Figure 23 is performed in similar fashion to a binary tree search. The spatial support of a given data value in a given frequency band is the same as two data values in the octave above it in frequency. Thus the wavelet decomposition is visualized as an array of binary trees such as is illustrated in Figure 23, each tree representing a spatial locality. The greater the number of transform octaves, the higher the trees extend upward and the fewer their number.

As illustrated in Figure 23, each of the data values of the decomposition represents a feature which is either "interesting" to the human visual system, or it represents a feature that is "non-interesting" to the human visual system. A data value representing an edge of an object in an image or an edge-like feature is an example of an "interesting" data value. The encoding method is a depth first search, which starts at the trunk of a tree, ascends up the branches of the tree that are interesting, and terminates at the non-interesting branches. After all the branches of a tree have been ascended until a non-interesting data value is encountered or until the top of the branch is reached, the encoding of another tree is begun. Accordingly, as the encoding method follows the interesting data values of Figure 23 from octave 2 to octave 1 to octave 0, the edge is followed from low to high frequency resolution and an increasingly better approximation to the spatial position and shape of the edge is made. Conversely, if at any stage, a non-interesting data value is found, the search is terminated for data values above that non-interesting data value. The higher frequency data values of the tree above a non-interesting data value are assumed to be non-interesting because the corresponding low frequency data

values did not indicate the presence of an edge at this location. Any interesting data values that do exist in the higher frequency bands above a non-interesting data value in a low frequency band are rejected as noise.

The one-dimensional tree structure of Figure 23 is encoded as follows. The low frequency components carry visually important information and are therefore always considered to be "interesting". The method of encoding therefore starts with low frequency component A. This data value is encoded. Next, the octave 2 data value B is tested to determine if it represents an edge or an edge-like feature which is "interesting" to the human visual system. Because data value B is interesting, a token is generated representing that the bits to follow will represent an encoded data value. Interesting data value B is then encoded. Because this tree has not yet terminated, the method continues upward in frequency. Data value C of octave 1 is then tested. For purpose of this example, data value C is considered to be interesting as are data values A, B, C, D, G, H, J, L and M as illustrated in Figure 23. A token is therefore generated indicating an encoded data value will follow. After the token is sent, data value C is encoded. Because this branch has still not terminated in a non-interesting data value, the method continues upward in frequency. Data value D is tested to determine whether or not it is interesting. Because data value D is interesting, a token is generated and data value D is encoded. Because octave 0 is the highest octave in the decomposition, the encoding method tests the other branch originating from previous interesting data value C. Data value E however tests to be non-interesting. A non-interesting token is therefore generated. Data value E is not encoded and does not appear in the compressed data. With both branches originating at data value C terminated, the method proceeds down in frequency to test the remaining branches originating from the previous interesting data value B.

Data value F is, however, determined to be non-interesting. A non-interesting token is therefore generated and data value F is not encoded and does not appear in the encoded data. Because this branch has terminated, all data values higher in frequency above data value F are considered to be non-interesting. A decoding device receiving the sequence of encoded data values and tokens can determine from the non-interesting token that all corresponding higher frequency data values were considered to be non-interesting by the encoding device. The decoding device can therefore write the appropriate data values as non-interesting and write zeroes to these locations obviating the need for the encoding device to transmit each non-interesting data value above F. With the first tree encoded, the method proceeds to the next low frequency component, data value G. This is a low frequency component and therefore is always considered to be interesting. Data value G is therefore encoded. The method then proceeds to the next tree through blocks H, I, J, K and L in that order generating interesting and non-interesting tokens and encoding interesting data values. Similarly, after the second tree is terminated, low frequency component data value M is encoded. Data value N is determined to be non-interesting so a non-interesting token is sent and the encoding of the third tree is terminated.

In accordance with another embodiment of the present invention, a two-dimensional extension of the one-dimensional case is used. Rather than using binary trees, four branch trees are used. However, to create a practical image encoding method there are also real world factors to take into account. Using a single data value to predict whether the remainder of the tree is zero, is unreliable when dealing with noisy image data. A small two-by-two block of data values is therefore used as the node element in the tree structure of the two-dimensional embodiment. A decision as to whether or not an edge is

present is based on four data values which is more reliable than a decision based on single data value.

Figure 25 illustrates a tree structure representing a portion of the decomposition of Figure 18. The decomposition of Figure 18 may extend farther to the right and farther in a downward direction for larger two-dimensional arrays of image data values. Similarly, the tree structure of Figure 25 may extend farther to the right for larger arrays of data values. Figure 25 represents a decomposition only having octave 0 and 1 high frequency components. In the event that the decomposition had additional octaves of high frequency components, the tree structure would extend further upward. In contrast to the binary tree structure of Figure 23, the tree structure of Figure 25 is a four branch tree. The two-by-two block of four octave 1 data values HHHG is the root of a tree which extends upward in frequency to four HG two-by-two blocks. If another octave of decomposition were performed, another level of octave 2 high frequency two-by-two blocks would be inserted into the tree structure. Four HHHG octave 1 two-by-two blocks would, for example, have a single octave 2 HHHHHG block beneath them. The low frequency component would be denoted HHHHHH.

Figure 26 is a pictorial representation of the decomposition of the tree structure of Figure 25. As explained above with respect to Figure 15, the actual data values of the various denoted blocks are distributed throughout the two-dimensional array of data values. The two numbers separated by a comma in each of the boxes of Figure 25 denote the row and column of a data value of the two-dimensional array of Figure 18, respectively. Using this tree structure, it is possible to search through the transformed data values of Figure 18 encoding interesting two-by-two blocks of data values and ignoring non-interesting two-by-two blocks.

To describe how the two dimensional encoding method uses the tree structure to search through a decomposition,

some useful definitions are introduced. First an image *decomp* is defined with dimensions *WIDTH* by *HEIGHT* decomposed to number *OCTS* of octaves. A function *Access* is defined such that given some arguments, the function *Access* outputs the memory address of the specified data value in the wavelet decomposition *decomp*:

address = Access (oct, sub, x, y);

oct is the octave of the data value sought and is an integer value between 0 (the highest octave) and *OCTS-1* (the number of octaves of transformation OCTS minus one). *sub* indicates which of the *HH*, *HG*, *GH* or *GG* bands of the decomposition it is that the data value sought is found. The use of *sub* = *HH* to access the low pass data values is only valid when the value of *oct* is set to that of the lowest octave. The co-ordinates *x* and *y* indicate the spatial location from the top left hand corner of the sub-band specified by *oct* and *sub*. The range of valid values of *x* and *y* are dependent on the octave being accessed. *x* has a range of {0. . . $WIDTH/2^{oct+1}$}. y has a range of {0 . . . $HEIGHT/2^{oct+1}$}.

Given the function *Access* and a wavelet decomposition, a two-by-two block of data values can be read by the function *ReadBlock*.

```
block =  ReadBlock (decomp, oct, sub, x, y) {
         block[0][0] = decomp[Access(oct, sub, x, y)];
         block[0][1] = decomp[Access(oct, sub, x+1, y)];
         block[1][0] = decomp[Access(oct, sub, x, y+1)];
         block[1][1] = decomp[Access(oct, sub, x+1, y+1)];
}
```

The wavelet decomposition is passed to the function *ReadBlock* via the variable *decomp*. The two-by-two block of data values is returned through the variable *block*.

Once a two-by-two block of data values is read, a

decision is made as to whether the two-by-two block is visually "interesting" and should therefore be encoded or whether it is not and hence should be discarded. The decision is made by a function called *Threshold*. The arguments of the function *Threshold* are *block*, *oct* and *sub*. *Threshold* returns a boolean value *True* if the block is "interesting" and *False* if the block is "non-interesting".

If the block is determined to be interesting by the function *threshold*, it is encoded using a function called *EncodeBlock*. A function *SendToken* inserts a token before the encoded block to inform a decoding device which will later decode the compressed data whether the block to follow the token has been encoded (i.e. *BlockNotEmpty*) or has not been encoded (i.e. *BlockEmpty*). If a block is determined to be interesting, then a *BlockNotEmpty* token is sent, and the block is encoded; next the tree structure above the encoded block is ascended to better determine the location of the edge. The tree encoding procedure *SendTree* is therefore defined recursively as follows:

```
SendTree (decomp, oct, sub, x, y, Q) {
   block = ReadBlock (decomp, oct, sub, x, y);
   If Threshold (block, oct, sub, Q) {
      SendToken (BlockNotEmpty);
      EncodeBlock (block, oct, sub, Q);
      If (oct >0) {
         SendTree (decomp, oct-1, sub, 2*x, 2*y, Q);
         SendTree (decomp, oct-1, sub, 2*(x+1), 2*y, Q);
         SendTree (decomp, oct-1, sub, 2*x, 2*(y+1), Q);
         SendTree (decomp, oct-1, sub, 2*(x+1), 2*(y+1), Q);
      }
   } else SendToken (BlockEmpty);
}
```

The procedure *SendTree* is only used to encode high-pass component data values. In procedure *SendTree*

(*decomp, oct, sub, x, y, Q*), if the two-by-two block accessed by *ReadBlock* is determined to pass the threshold test, then *SendTree* (*decomp, oct-1, sub 2*X, 2*y, Q*) is used to test one of the next higher two-by-two blocks in the decomposition tree.

The low-pass data values are not considered to form part of the tree structure. The low-pass data values are encoded using another procedure *SendLPF*. In addition, the low-pass values are encoded using a different technique than that used in *EncodeBlock*, so a new procedure *EncodeBlockLPF* is required.

```
SendLPF (decomp, x, y, Q) {
    block = Readblock (decomp, OCTS-1, HH, x, y);
    EncodeBlockLPF (block, OCTS-1, Q);
}
```

Accordingly, to encode the entire image, *SendLPF* is applied to all the block locations within the low pass band and *SendTree* is applied to the all the block locations in the HG, GH and GG bands, within the lowest octave. A procedure *SendDecomp* is therefore defined that encodes the entire image decomposition:

```
SendDecomp (decomp, Q) {
    For (y=0; y<HEIGHT/2^OCTS; y=y+2)
    For (x=0; x<WIDTH/2^OCTS; x=x+2) {
        SendLPF (decomp, x, y, Q);
        SendTree (decomp, OCTS-1, HG, x, y, Q);
        SendTree (decomp, OCTS-1, GH, x, y, Q);
        SendTree (decomp, OCTS-1, GG, x, y, Q);
    }
}
```

Accordingly, the above functions define a method for encoding wavelet decomposed images. In terms of speed of encoding for real-world images, many of the trees are

terminated within the initial octaves so much of the decomposition is not examined. Due to this termination of many trees in the initial octaves, many data values need not be encoded which results in reducing the memory bandwidth and block processing required to implement the compression/decompression method. Provided the functions *Threshold*, *EncodeBlockLPF* and *Access* require only simple calculations, the decomposed data values are rapidly encoded.

To implement the function *Access*, a table containing all the addresses of the data values of the two-dimensional tree decomposition may be accessed using the variables *x*, *y*, *sub* and *oct*. For a small image having a small number of data values, this table lookup approach is reasonable. For images having, for example, approximately 80 different values of *x*, 60 different values of *y*, four different values of *sub*, and 3 or 4 values for *oct*, this table would contain approximately 150,000 10-bit locations. A less memory intensive way of determining the same X and Y addresses from the same variables is desirable.

In accordance with one embodiment of the present invention, a function is used to determine the X and Y addresses from the variables *x*, *y*, *sub* and *oct*. Address X, for example, may be determined as follows:

$$X = ((x << 1) + (sub >> 1)) << oct$$

where << denotes one shift to the right of value *x* and where >> denotes one shift to the left.

Address Y, for example, may be determined as follows:

$$Y = ((y << 1) + (1 \& sub)) << oct$$

where & denotes a bit-wise AND function.

In a high performance system, the function *Access* may be implemented according to the following method. The

recursive function call and the table lookup methods described above are often too slow to implement in real time software or in hardware. Figures 27 and 28 illustrate how the tree decomposition of Figure 25 is traversed in order to generate tokens and encode two-by-two blocks of data values. The X and the Y in Figures 27 and 28 denote coordinate addresses in the two-dimensional matrix of Figure 18. In order to traverse the tree of the decomposition of Figure 25, it is necessary to be able to determine the X and Y addresses of the data values represented in Figure 25. Figure 27 illustrates how the X and Y address of a two-by-two block of data values are determined for those two-by-two blocks of data values located in octave 0 of the decomposition of Figure 25. Similarly, Figure 28 illustrates how the X and Y addresses of the three two-by-two blocks of data values in octave 1 of the decomposition as well as the one two-by-two block of data values of the low pass component of the decomposition of Figure 25 are determined. X as well as Y are each functions of *oct*, *TreeRoot*, and *sub*. The values of sub_x and sub_y are determined by the sub-band of the two-by-two block of data values sought.

Figure 29 is a chart illustrating the values of sub_x and sub_y for each sub-band of the decomposition. If, for example, a two-by-two block of data values is sought in the HH band, then the values of sub_x and sub_y are 0 and 0, respectively. The values $TreeRoot_x$ and $TreeRoot_y$ together denote the particular tree of a decomposition containing the particular two-by-two block of the data values sought.

In Figures 27 and 28, the rectangles represent digital counters. The arrows interconnecting the rectangles indicate a sequence of incrementing the counters. For example, the right most rectangle in Figure 27, which is called counter C1, has a least significant bit represented in Figure 27 as bit $C1_x$ and a most significant bit represented as bit $C1_y$. Similarly, the next rectangle to the left in Figure 27 represents a

digital counter C2 having two bits, a least significant bit $C2_x$ and a most significant bit $C2_y$. The structure of the X, Y address depends on the octave in which the two-by-two block of data values being sought resides. To generate the X, Y address in octave $oct = 1$, the counter C1 is not included, the sub_x and sub_y bits indicating the sub-band bits are shifted one place to the left, and the least significant bits are filled with zeros. The incrementing of the counters in Figure 28 proceeds as illustrated by the arrows.

To determine the X and Y addresses of the four data values of the low pass component HHHH of Figure 25, Figure 28 is used. Because the two-by-two block of data values being sought is a two-by-two block of the low pass component, the values of sub_x and sub_y are 0, 0 as required by the table of Figure 29. The C2 counter of Figure 28 increments through the four possible values of $C2_x$ and $C2_y$ to generate the four addresses in the two-by-two block of data values of the HHHH in the low pass component of Figure 25. The value of $TreeRoot_x$ and $TreeRoot_y$ are zeroes because this is the first tree of the decomposition. For subsequent trees of the decomposition, $TreeRoot_x$ and $TreeRoot_y$ are incremented as illustrated by the arrows in Figure 28 so that the X and Y addresses of the other two-by-two blocks of data values in the low pass component of the tree decomposition can be determined. After this HHHH two-by-two block of data values is located, the four data values are encoded and the search through the tree structure proceeds to the two-by-two block of data values in octave 1 denoted HHHG in Figure 25. To determine the X and Y addresses of the four data values of this two-by-two block, the value of bits sub_x and sub_y are changed in accordance with Figure 29. Because this two-by-two block is in the HG sub-band, the values of sub_x and sub_y are 0 and 1, respectively. The C2 counter is then incremented through its four values to generate the four addresses of the four data values in that block. Supposing, that this

two-by-two block is determined to be "interesting" then an interesting token is sent, each of the four data values of the block are encoded, and the tree is then ascended to the two-by-two block of data values in octave 0 denoted HG#1. These four addresses are determined in accordance with Figure 27. Because the sub-band is sub-band HG, the values of the bits sub_x and sub_y are 0 and 1, respectively. Counter C1 is then incremented so that the four addresses illustrated in the two-by-two block octave 0 HG#1 of Figure 25 are generated. If the two-by-two block is interesting, then the interesting token is sent and the four data values are encoded. If the two-by-two block is determined not to be interesting, then a non-interesting token is sent and the four data values are not encoded. The search through the tree structure of the decomposition then proceeds to octave 0 block HG#2. After the four addresses of the octave 0 block HG#1 are generated, the $C2_x$ bit of the C2 counter is incremented in accordance with the arrows shown in Figure 27. Accordingly, the octave 0 block HG#2 is addressed when once again the C1 counter increments through its four states. If the data values of this two-by-two block are determined to be "interesting", an interesting token is sent followed by the encoded data values. If the data values of the two-by-two block are determined to be non-interesting, then a non-interesting token is sent. After all the search of the four two-by-two blocks of the octave 0 HG sub-band are searched, then that HG tree is terminated and the search proceeds to determine the four addresses of the four data values of the octave 1 HHGH two-by-two block. In accordance with this technique, it is possible to traverse the structure of the decomposition and determine the addresses of any two-by-two block in any octave or any sub-band with minimum overhead. Moving between consecutive addresses or descending trees is a simple operation when compared to the snaking address path used by other compression methods such as JPEG.

When implemented in software, this technique enables real time compression and decompression whereas other techniques may be too slow. If implemented in hardware, this technique provides for a reduced gate count and an efficient implementation. Although this example shows one way of traversing the tree structure of wavelet transform decomposition, it is possible to traverse the tree structure in other ways simply by changing the control structure represented in Figures 27 and 28 to allow for a different traversal of the tree structure. For example, all of the low pass HHHH blocks can be located and encoded first followed by all of the HHHG tree of the decomposition, and then all of the HHGH trees, and then all of the HHGG trees.

QUANTIZATION

Each data value of each two-by-two block of the tree decomposition which is determined to be "interesting" is quantized and then Huffman encoded. A linear mid-step quantizer with double-width-0 step is used to quantize each of the data values. Figure 30 is an illustration of the quantization of a 10-bit twos complement data value. The range of the 10-bit data value to be quantized ranges from -512 to 511 as illustrated by the numbers above the horizontal line in Figure 30. This range is broken up into a plurality of steps. Figure 31 represents one such step of data values which extends from 128 to 256 in Figure 30. All incoming data values having values between 128 and 255 inclusive are quantized by dividing the data value by the value *qstep*. Accordingly, the data value A having a value of 150 as illustrated in Figure 31 is divided by the *qstep* value 128 and results in a *qindex* number of 1. Integer division is used to generate *qindex* and the fractional part of the remainder is discarded. Once the *qindex* number is determined, the *qindex* number is Huffman encoded. An overall *Q* value is sent once per frame of compressed data values. The value *qstep* is

determined from the overall Q value as described below.

To inverse quantize the *qindex* number and the *qstep* value to determine the value of the transformed data values before inverse transformation, the device decoding the incoming quantized values calculates the value of *qstep* using the value of Q according to a method described below. Once the value of *qstep* in determined, *qindex* for a given data value is multiplied by *qstep*.

In the example of Figure 31, *qindex* value 1 times *qstep* 128 results in an inverse quantized value of 128. If this inverse quantized value of 128 were used, however, all the data values in the step 128 through 255 would be inverse quantized to the value of 128 at the left end of the step. This would result in unacceptably large errors. On the other hand, if all the data values in the range of Figure 31 were inverse quantized to the mid-step value 191, then less error would result. Accordingly, an inverse quantized value *qvalve* can be calculated from *qindex* and *qstep* as follows:

$$qvalue(qindex, qstep) = \begin{cases} qindex * qstep - \left(\frac{qstep}{2} - 1\right) & \text{if } qindex < 0 \\ 0 & \text{if } qindex = 0 \\ qindex * qstep + \left(\frac{qstep}{2} - 1\right) & \text{if } qindex > 0 \end{cases}$$

The human visual system, however, has different sensitivities to quantization errors depending upon the particular sub-band containing the quantized data values. The human visual system performs complex non-linear processing. Although the way the human visual system relates image intensities to recognizable structures is not well understood, it is nevertheless important to take advantage of as much information about the human visual system as possible in order to maximize compression ratio versus picture quality. The wavelet transform approximates the initial image processing performed by the human brain. Factors such as spatial frequency response and Weber's Law can therefore be applied directly to the

wavelet transformed data values because the transformed data values are in a convenient representation.

Figure 32 shows the sensitivity of the human eye to spatial frequency. Spatial frequency is measured in cycles c per visual angle θ. A screen is positioned at a distance d from an observer as illustrated in Figure 33. A light of sinusoidally varying luminance is projected onto the screen. The spatial frequency is the number of luminance cycles c per visual degree θ at distance d. Note from Figure 32 that the sensitivity of the human eye varies with spatial frequency. Accordingly, the value of *qstep* is varied depending on the octave and sub-band of the data valve being quantized. The *qstep* at which a data valve is quantized is determined from the variables *oct, sub* and *Q* for that data valve as follows:

$$qstep(oct,sub,Q) = Q * hvs\_factor(oct,sub)$$

$$hvs\_factor(oct,sub) = \begin{cases} \sqrt{2} & \text{if } sub=GG \\ 1 & \text{otherwise} \end{cases} * \begin{cases} 1.00 & \text{if } oct=0 \\ 0.32 & \text{if } oct=1 \\ 0.16 & \text{if } oct=2 \\ 0.10 & \text{if } oct=3 \end{cases}$$

The scaling factors 1.00, 0.32, 0.16 and 0.10 relate to the spatial frequency scale of Figure 32 to take into account the frequency dependent sensitivity of the human eye.

It is to be understood that scaling factors other than 1.00, 0.32, 0.16 and 0.10 could be used. For example, other scaling factors can be used where the quantizer is used to compress audio data which is received by the human ear rather than by the human eye. Moreover, note that the sub-band GG is quantized more heavily than the other sub-bands because the sub-band GG contains diagonal information which is less important to the human eye than horizontal and vertical information. This method can also be extended down to the level of two-by-two blocks of data values to further tailor the degree of quantization to the human visual system. The function

hvs_factor which has only two parameters in the presently described embodiment is only one embodiment of the present invention. The function *hvs_factor*, for example, can take into account other characteristics of the human visual system other than *oct* and *sub,* such as the luminance of the background and texture masking.

THRESHOLDING

For each new two-by-two block of data values in the tree decomposition, a decision must be made as to whether the block is "interesting" or "non-interesting". This can be done by the function *threshold*:

$$threshold(block,limit) = limit > \sum_{y=0}^{1}\sum_{x=0}^{1} |block[y][x]| \qquad \text{(equ. 60)}$$

The sum of the absolute values of the data values of the block *block* is determined as is represented by the double summation to the right of the less than sign and this value is compared to a threshold value *limit*. "Interesting" blocks are those blocks, for which the sum of the absolute values of the four data values exceeds the value *limit*, whereas "non-interesting" blocks are those blocks for which the sum is less than or equal to the value *limit*.

The value *limit* takes into account the variable quantizer step size *qstep* which varies with octave. For example, a two-by-two block of data values could be determined to pass the test *threshold*, but after quantizing by *qstep* could result in four zero quantized values. For example, all data values between -128 and 127 are quantized to have a quantized *qindex* of zero as is shown in Figure 30 even if some of those data values are determined to correspond with an "interesting" two-by-two block. For this reason, the value *limit* is calculated according to the equation:

limit = 4**Bthreshold***qstep* (equ. 61)

In this equation "*Bthreshold*" is base threshold image factor. In the presently described example, this base threshold is equal to 1.0. The value of 1.0 for the base threshold *Bthreshold* was determined through extensive experimentation on test images. The factor 4 in equation 61 is included to account for the fact that there are four data values in the block under consideration. In this way blocks are not determined to be interesting, the data values for which the quantizer will later reduce to zeros. This weighted threshold factor *limit* also reduces the number of operations performed in the quantizer because a fewer number of data values are quantized.

HUFFMAN CODING

The wavelet transform produces transformed data values whose statistics are vastly different from the data values of the original image. The transformed data values of the high-pass sub-bands have a probability distribution that is similar to an exponential or Laplacian characteristic with mean zero.

Figure 34 shows the distribution of high pass data values in a four octave wavelet decomposition of the test image Lenna. Figure 35 shows the distribution of the data values of the test image Lenna before wavelet transformation. The low-pass component data values have a flat distribution that approximates the distribution of luminance and chrominance values in the original image. The high and low pass data values are encoded differently for this reason.

The low pass component data values are encoded by the function *EncodeBlockLPF* as follows:

```
EncodeBlockLPF ( block, OCT-1, Q) {
        Output ( block[0][0]/qstep( OCT-1, HH, Q));
        Output ( block[0][1]/qstep( OCT-1, HH, Q));
        Output ( block[1][0]/qstep( OCT-1, HH, Q));
```

```
Output ( block[1][1]/qstep( OCT-1, HH, Q));}
```

After encoding, the low-pass data values are quantized and output into the compressed data stream. The low pass data values are not Huffman encoded.

The high frequency component data values which pass the threshold test are quantized and Huffman encoded to take advantage of their Laplacian distribution. Function *EncodeBlock* performs the quantization and the Huffman encoding for each of the four data values of an interesting high frequency component block *block*. In the function *EncodeBlock*, the variable *sub* is provided so that when function *qstep* is called, different quantization *qstep* values can be used for different high frequency component sub-bands. The function *huffman* performs a table lookup to a fixed Huffman code table such as the table of Table 3. The function *EncodeBlock* is defined as follows:

```
EncodeBlock (block, oct, sub, Q) {
    Output(huffman(block[0][0]/qstep(oct, sub, Q)));
    Output(huffman(block[0][1]/qstep(oct, sub, Q)));
    Output(huffman(block[1][0]/qstep(oct, sub, Q)));
    Output(huffman(block[1][1]/qstep(oct, sub, Q)));
}
```

qindex	Huffman code
-38 . . . -512	1 1 0 0 0 0 0 0 1 1 1 1 1 1 1 1
-22 . . -37	1 1 0 0 0 0 0 0 1 1 1 1 (|*qindex*| -22)
-7 . . -21	1 1 0 0 0 0 0 0 (|*qindex*| -7)
-6	1 1 0 0 0 0 0 1
. . .	. . .
-2	1 1 0 1
-1	1 1 1
0	0
1	1 0 1
2	1 0 0 1
. . .	. . .
6	1 0 0 0 0 0 0 1
7 . . 21	1 0 0 0 0 0 0 0 (|*qindex*| -7)
22 . . 37	1 0 0 0 0 0 0 0 1 1 1 1 (|*qindex*| -22)
38 . . 511	1 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1

Table 3

The second bit from the left in the Huffman code of Table 3 is a sign bit. The value $|qindex|-7$ is represented with 4 bits in the case $7 \leq |qindex| \leq 21$. The value $|qindex|-22$ is represented with 4 bits in the case $22 \leq |qindex| \leq 37$).

ENCODING OF TOKENS

At high compression ratios the number of bits in the compressed data stream used by tokens may be reduced by amalgamating groups of "non-interesting" tokens. This can be achieved by introducing new tokens. In accordance with one embodiment of the present invention, two new tokens, *OctEmpty* and *OctNotEmpty* are used. For a high pass component block in a tree above octave zero, there are four branches. The additional pair of tokens indicate

whether all four are non-interesting. If all four are non-interesting, only a single *OctEmpty* token need be sent. Otherwise, an *OctNotEmpty* token is generated before the four branches are encoded. The particular token scheme described above was selected more to simplify the hardware and software implementations than it was to achieve in the best compression ratio possible. Other methods of representing relatively long sequences of token bits in the compressed data stream using other tokens having a relatively fewer number of bits may be used in place of the tokens *OctEmpty* and *OctNotEmpty* to achieve higher compression ratios.

VIDEO ENCODING AND DECODING

In comparison with the coding of a still image, the successive images of a video sequence typically contain much redundant information. The redundancy of this information is used to reduce the bit rate. If a location in a new frame of the video contains the same or substantially the same information as a corresponding location in the previous old frame of video, that portion of the new frame need not be encoded and introduced into the compressed data. This results in a reduction in the total number of bits in the encoded bit stream.

Figure 36 illustrates a video encoder 31 and a video decoder 32. A video input signal is transformed by a forward wavelet transform block 33, the output of which is written to a new frame store 34. The first frame of video information in the new frame store 34 is referred to as the new frame because no previous frame exists in the old frame store 35 for containing an old frame. A comparison tree encoder 36 therefore generates tokens and transformed data values as described above from the data values output from new frame store 34. The transformed data values are quantized by quantizer 37 into *qindex* levels. These *qindex* levels are then Huffman coded by the Huffman encoder 38. The resulting encoded data values are then

combined with the tokens in buffer 38A to form a decompressed data bit stream 39.

An essential part of this method is that the old frame present in the video encoder 31 is exactly the same as the old frame 40 present in the video decoder 32. This allows the decoder 32 to be able to correctly decode the encoded bit stream 39 due to the fact that the encoded bit stream contains differences between new and old images and due to the fact that parts of the new frame are not sent due to compression. An inverse quantizer 41 is therefore provided in the video encoder 31 to inverse quantize the *qindex* levels and to store the old frame as sent into old frame store 35 for future comparison with the next frame of the video input signal.

In the video decoder 32, the compressed data stream 39 is received by a buffer 42. The tokens are separated from the Huffman encoded *qindex* levels. The Huffman encoded *qindex* levels are supplied to a Huffman decoder 43, the output of which is supplied to an inverse quantizer 44. The output of the inverse quantizer 44 is written into old frame store 40 under the control of the comparison tree decoder 45. Comparison tree decoder 45 determines what is written into the old frame store 40, depending in part on the tokens received from buffer 42. Once a new frame of transformed data values is present in old frame store 40, an inverse wavelet transform 46 inverse transforms that frame of transformed data values into a corresponding video output signal. To prevent the inverse wavelet transform 46 from overwriting and therefore corrupting the contents of old frame store 40 when it reconstructs data values corresponding to the original new frame data values, an intermediate frame store 47 is maintained.

The octave one HHHG, HHGH, HHGG, and HHHH from Figure 25 are read from the old frame store 40 by the inverse wavelet transform 46 to perform the octave 1 inverse transform as described above. However, the resulting

octave 0 HH sub-band, output from the inverse wavelet tranform 46 is now written to the intermediate frame store 47, so as not to corrupt the old frame store 40. For the octave 0 inverse wavelet transform, the HG, GH, and GG sub-bands are read from the old frame store 40, and the HH sub-band is read from the intermediate frame store 47, to complete the inverse wavelet transform.

When the second frame of compressed video data 39 is received by the video decoder 32, the tokens received by the comparison tree decoder 45 are related to the contents of the previous frame of video information contained in old frame store 40. Accordingly, the video decoder 32 can reconstruct the latest frame of video data using the contents of the frame store 40 and the data values encoded in the compressed data stream 39. This is possible because the compressed data stream contains all the information necessary for the video decoder 32 to follow the same traversal of the tree of the decomposition that the encoder used to traverse the tree in the generation of the compressed data stream. The video decoder 32 therefore works in lock step with the video encoder 31. Both the encoder 31 and the decoder 32 maintain the same mode at a corresponding location in the tree. When the encoder 31 determines a new mode, it incorporates into the compressed data stream 39 a corresponding token, which the video decoder 32 uses to assume that new mode.

Figure 37 illustrates the modes of operation of one possible embodiment of the present invention. To explain the operation of the video encoder 31 and the video decoder 32, an example is provided. The initial frame of the video sequence is processed by the video encoder 31 in still mode. Still mode has three sub-modes: STILL, VOID_STILL, and LPF_STILL. The low pass two-by-two blocks of data values of the decomposition cause the comparison tree encoder 36 of video encoder 31 to enter the LPF_STILL sub-mode. In this sub-mode, the four data values of the two-by-two block are quantized but are not Huffman

encoded. Similarly, no token is generated. The successive low pass component two-by-two blocks of data values are successively quantized and output into the compressed data stream 39.

Next, the lowest frequency octave of one of the sub-bands is processed by the comparison tree encoder 36. This two-by-two block of data values corresponds with block HHHG illustrated in Figure 25. The four data values of this two-by-two block are tested against the threshold *limit* to determine if it is "interesting". If the two-by-two block HHHG is interesting, then a single bit token 1 is generated, as illustrated in Figure 37, the mode of the comparison tree encoder remains in STILL mode, and the four data values of the two-by-two block HHHG are successively quantized and encoded and output into the compressed data stream 39.

For the purposes of this example, block HHHG is assumed to be interesting. The tree structure of Figure 25 is therefore ascended to octave 0 two-by-two block HG#1. Because the comparison tree encoder 31 remains in the STILL mode, this block is encoded in the STILL mode. The four data values of block HG#1 are tested to determine whether or not they are interesting. This sequence of testing the successive blocks of the tree structure is repeated as described above.

After the traversal of the four octave 0 sub-blocks HG#1, HG#2, HG#3 and HG#4, the comparison tree encoder 36 proceeds in the tree structure to the two-by-two block of data values in octave 1, block HHGH. For purposes of this example, this two-by-two is non-interesting. After the comparison tree encoder 36 reads the four data values, the result of the threshold test indicates a non-interesting two-by-two block. As illustrated in Figure 37, the encoder 31 which is in the still mode now generates a single bit token 0 and the comparison tree encoder 36 enters the VOID_STILL sub-mode. Although no additional information is output into the compressed data stream 39,

the comparison tree encoder 36 proceeds to write 0's into the four locations of the two-by-two block HHGH, as well as all the locations of the two-by-two blocks in the tree above the non-interesting two-by-two block HHGH. In the example of Figure 25, the comparison tree encoder 36 writes 0's into all the addresses of blocks HHGH, GH#1, GH#2, GH#3 and GH#4. This zeroing is performed because the video decoder 32 will not be receiving the data values corresponding to that tree. Rather, the video decoder 32 will be receiving only a non-interesting token, a single bit 0. The video decoder 32 will therefore write zeros into frame store 40 in the remainder of the corresponding tree. In order to make sure that both the video encoder 31 and the video decoder 32 have exactly the same old frame 35 and 40, the video encoder too must zero out those non-interesting blocks.

After the first frame of video data has been encoded and sent in STILL mode, the next frame of video data is processed by the video encoder 31. By default, the encoder now enters SEND mode. For lowpass frequency component two-by-two blocks, the video encoder 31 enters the LPF_SEND mode as illustrated in Figure 37. The encoding of such a lowpass component two-by-two block corresponds with the encoding of two-by-two block HHHH in Figure 25. However, now the comparison tree encoder 36 has both a new frame in frame store 34 as well as an old frame in frame store 35. Accordingly, the comparison tree encoder 36 determines the arithmetic difference of the respective four data values in the new frame from the four data values in the old frame at the corresponding position and compares the sum of those differences with a compare threshold. The compare threshold, compare, is calculated from a base compare threshold "Bcompare" as in the case of the previous threshold which determines which blocks are interesting, similar to equations 60 and 61. If the sum of the differences is less than the compare threshold, then the video encoder 31 sends a single bit token 0 and

remains in the LPF_SEND mode, as illustrated in Figure 37. The video encoder 31 does not transmit any data values corresponding to the lowpass frequency component two-by-two block.

If, on the other hand, the sum of the arithmetic differences exceeds the compare threshold, then a single bit token 1 is generated, as illustrated in Figure 37. In this case, the video encoder 31 sends the arithmetic differences of each of the successive four data values of the new frame versus the old frame to the quantizer 37 and then to the Huffman encoder 38. The arithmetic differences are encoded and sent rather than sending the actual data values because this results in fewer bits due to the fact that the two blocks in the new and old frames are quite similar under normal circumstances.

When the video encoder 31 proceeds to encode the octave 1 sub-band HHHG, as illustrated in Figure 25, the video encoder 31 enters the SEND mode, as illustrated in Figure 37. In this mode, the comparison tree encoder 36 compares the data values of the new two-by-two block with the data values of the old two-by-two block and performs a series of arithmetic operations to generate a series of flags, as illustrated in Figure 38. Based on these flags, the video encoder 31 generates a 2-bit token and enters one of four new modes for that two-by-two block. If, for example, the two-by-two block HHHG in Figure 25 is received by the video encoder 31, then flags *ozflag*, *nzflag*, *new_z*, *noflag*, *motion*, *origin*, and *no_z* are determined. The values of these flags are determined as:

$$nz = \sum_{x=0}^{1}\sum_{y=0}^{1} |new[x][y]| \qquad \text{(equ. 62)}$$

$$no = \sum_{x=0}^{1}\sum_{y=0}^{1} |new[x][y] - old[x][y]| \qquad \text{(equ. 63)}$$

$$oz = \sum_{x=0}^{1}\sum_{y=0}^{1} |old[x][y]| \qquad \text{(equ. 64)}$$

$$nzflag = nz < limit \quad \text{(equ. 65)}$$

$$noflag = no < compare \quad \text{(equ. 66)}$$

$$origin = nz \le no \quad \text{(equ. 67)}$$

$$motion = ((nz + oz) << oct) \le no \quad \text{(equ. 68)}$$

$$new\_z = |new[x][y]| < qstep\ ,\ 0 \le x,\ y,\ \le 1 \quad \text{(equ. 69)}$$

$$no\_z = |new[x][y] - old\ [x][y]| < qstep,\ 0 \le x, y \le 1 \quad \text{(equ. 70)}$$

$$ozflag = \{old[x][y] = 0;\ \text{for all } 0 \le x,\ y \le 1\} \quad \text{(equ. 71)}$$

Based on the values of these flags, the new mode for the two-by-two block HHHG is determined, from Figure 38.

If the new mode is determined to be the SEND mode, the 2-bit token 11 is sent as indicated in Figure 37. The arithmetic differences of the corresponding four data values are determined, quantized, Huffman encoded, and sent into the compressed data stream 39.

In the case that the flags indicate the new mode is STILL_SEND, then the 2-bit token 01 is sent and the new four data values of the two-by-two block are quantized, Huffman encoded, and sent. Once having entered the STILL_SEND mode, the video encoder 31 remains in the STILL_SEND mode until the end of the tree has been reached. In this STILL_SEND mode, a single bit token of either 1 or 0 precedes the encoding of each block of data values. When the VOID mode is entered from STILL_SEND mode, the video encoder 31 generates a single bit 0 token, then places zeros in the corresponding addresses for that two-by-two block, and then proceeds to place zeros in the addresses of data values of the two-by-two blocks in the tree above.

In the event that the flags indicate that the video encoder 31 enters the VOID mode from SEND mode, a 2-bit token 10 is generated and the four data values of that two-by-two block are replaced with zeros. The VOID mode also results in the video encoder 31 placing zeros in all addresses of all data values of two-by-two blocks in the tree above.

In the case that the flags indicate that there is no

additional information in the tree being presently encoded, namely, the new and the old trees are substantially the same, then a 2-bit token of 00 is generated and the video encoder 31 proceeds to the next tree in the decomposition.

In general, when the video encoder 31 enters VOID mode, the video encoder will remain in VOID mode until it determines that the old block already contains four zero data values. In this case, there is no reason to continue in VOID mode writing zeros into that two-by-two block or the remainder of the blocks in the tree above because it is guaranteed that the old tree already contains zeros in these blocks. This is true because the old tree in frame store 35 has previously been encoded through the inverse quantizer 41.

Because the video decoder 32 is aware of the tree structure of the decomposition, and because the video encoder 31 communicates with the video decoder 32 using tokens, the video decoder 32 is directed through the tree structure in the same manner that the video encoder 31 traverses the tree structure in generating the compressed data stream 39. In this way the video decoder 32 writes the appropriate data values from the decompressed data stream 39 into the corresponding positions of the old data frame 40. The only flag needed by the video decoder 32 is the *ozflag*, which the video decoder obtains by reading the contents of old frame store 40.

RATE CONTROL

All transmission media and storage media have a maximum bandwidth at which they can accept data. This bandwidth can be denoted in terms of bits per second. A standard rate ISDN channel digital telephone line has, for example, a bandwidth of 64 kbits/sec. When compressing a sequence of images in a video sequence, depending upon the amount of compression used to compress the images, there may be a relatively high number of bits per second

generated. This number of bits per second may in some instances exceed the maximum bandwidth of the transmission media or storage device. It is therefore necessary to reduce the bits per second generated to insure that the maximum bandwidth of the transmission media or storage device is not exceeded.

One way of regulating the number of bits per second introduced into the transmission media or storage device involves the use of a buffer. Frames having a high number of bits are stored in the frame buffer, along with frames having a low number of bits, whereas the number of bits per second passing out of the buffer and into the transmission media or storage device is maintained at a relatively constant number. If the buffer is sufficiently large, then it is possible to always achieve the desired bit rate as long as the overall average of bits per second being input into the buffer over time is the same or less than the maximum bit rate being output from the buffer to the transmission media or storage device.

There is, however, a problem associated with large buffers in video telephony. For a large buffer, there is a significant time delay between the time a frame of video data is input into the buffer and time when this frame is output from the video buffer and into the transmission media or storage device. In the case of video telephony, large buffers may result in large time delays between the time when one user begins to speak and the time when another user begins to hear that speech. This time delay, called latency, is undesirable. For this reason, buffer size is specified in the standard H.261 for video telephony.

In accordance with one embodiment of the present invention, a rate control mechanism is provided which varies the number of bits generated per frame, on a frame by frame basis. Due to the tree encoding structure described above, the number of bits output for a given frame is dependent upon the number of trees ascended in

the tree encoding process. The decisions of whether or not to ascend a tree are made in the lowest high frequency octaves of the tree structure. As can be seen from Figure 25, there are relatively few number of blocks in the lowest frequency of the sub-bands, as compared to the number of blocks higher up in the sub-band trees. Given a particular two-by-two block in the tree structure, it is possible to decrease the value of Q in the equation for the threshold *limit* until that particular block is determined to be "interesting". Accordingly, a particular Q is determined at which that particular block becomes interesting. This process can be done for each block in the lowest frequency HG, GH and GG sub-bands. In this way, a histogram is generated indicating a number of two-by-two blocks in the lowest frequency of the three sub-bands which become interesting at each particular value of Q.

From this histogram, a relationship is developed of the total number of two-by-two blocks in the lowest frequency of the three sub-bands which are interesting for a given value of Q. Assuming that the number of blocks in the lowest frequency octave of the three sub-bands which are interesting for a given value of Q is representative of the number of bits which will be generated when the tree is ascended using that given value of Q, it is possible to determine the value of Q at which a desired number of bits will be generated when that frame is coded with that value of Q. Furthermore, the greater the threshold is exceeded, the more bits may be needed to encode that tree. It is therefore possible to weight by Q the number of blocks which are interesting for a given value of Q. Finally, the Q values so derived should be averaged between frames to smooth out fluctuations.

The encoder model RM8 of the CCITT Recommendation H.261 is based on the DCT and has the following disadvantages. The rate control method used by RM8 is a linear feedback technique. Buffer fullness is

proportional to Q. The value of Q must be adjusted after every group of blocks (GOB) to avoid overflow or underflow effects. This means that parts of the image are transmitted at a different level quality from other parts. During parts of the image where little change occurs, Q drops which can result in uninteresting areas being coded very accurately. The objects of interest are, however, usually the moving ones. Conversely, during the coding of areas of high activity, Q rises creating large errors in moving areas. When this is combined with a block based transform, the errors can become visually annoying.

The method of rate control described in connection with one embodiment of the present invention uses one value of Q for the whole frame. The value of Q is only adjusted between frames. All parts of an image are therefore encoded with the same value of Q. Moreover, because the tree structure allows a relatively few number of blocks to be tested to determine an estimate of the number of bits generated for a given frame, more intelligent methods of varying Q to achieve an overall desired bit rate are possible than are possible with conventional compression/decompression techniques.

TREE BASED MOTION ESTIMATION

Figure 39 represents a black box 1 on a white background 2. Figure 40 represents the same black box 1 on the same white background 2 moved to the right so that it occupies a different location. If these two frames of Figures 39 and 40 are encoded according to the above described method, there will be a tree in the wavelet decomposition which corresponds with the white-to-black edge denoted 3 in Figure 39. Similarly, there will be another tree in the wavelet decomposition of the image of Figure 40 which represents the white-to-black edge 3' the wavelet decomposition of the image of Figure 40. All of the data values corresponding to these two trees will be determined to be "interesting" because edges result in

interesting data values in all octaves of the decomposition. Moreover, due to the movement of the corresponding edge of black box 1, all the data values of the edges of both of these two trees will be encoded as interesting data values in the resulting compressed data stream. The method described above therefore does not take into account that it is the same data values representing the same white-to-black edge which is present in both images but which is just located at a different location.

Figure 41 is a one dimensional representation of an edge. The corresponding low path component data values are not illustrated in Figure 41. Data values 4, 5, 6, 7, 8, and 9 represent the "interesting" data values of Figure 41 whereas the other data values have low data values which makes those blocks "non-interesting". In the representation of Figure 41, data values 4 and 5 are considered a single two data value block. Similarly, blocks 6 and 7 are considered a single block and blocks 8 and 9 are considered a single block. Figure 41, although it is a one dimensional representation for ease of illustration, represents the edge 3 of the frame of Figure 39.

Figure 42 represents the edge 3' shown in Figure 40. Figure 42 indicates that the edge of black box 1 has moved in location due to the fact that the values 19 and 21 which in Figure 41 were in the two data value block 8 and 9 are located in Figure 42 in the two data value block 10 and 11. In the encoding of Figure 42, rather than encoding and sending into the compressed data stream the values 19 and 21, a control code is generated which indicates the new locations of the two values. Although numerous control codes are possible, only one embodiment is described here.

When the two data value block 10 and 11 is tested to determine whether it is interesting or not, the block tests to be interesting. The neighboring blocks in the

old frame are, however, also tested to determine whether the same values are present. In this case, the values 19 and 21 are determined to have moved one two data value block to the right. An "interesting with motion" token is therefore generated rather than a simple "interesting" token. A single bit 1 is then sent indicating that the edge represented by values 19 and 21 has moved to the right. Had the edge moved to the left, a control code of 0 would have been sent indicating that the edge represented by values 19 and 21 moved one location to the left. Accordingly, in the encoding of Figure 42, an "interesting with motion" token is generated followed by a single control code 1. The interesting values 19 and 21 therefore need not be included in the compressed data stream. The video decoder receiving this "interesting with motion" token and this control code 1 can simply copy the interesting values 19 and 21 from the old frame into the indicated new location for these values in the new frame obviating the need for the video encoder to encode and transmit the actual interesting data values themselves. The same token and control codes can be sent for the two data values corresponding to a block in any one of the octaves 0, 1 or 2.

Figure 43 represents the motion of the edge 3 of Figure 39 to a new location which is farther removed than is the new location of black box 1 shown in Figure 40. Accordingly, it is seen that the values 20 and 21 are located to the right at the two data value block 12 and 13. In the encoding of this two data value block 12 and 13 a token indicating "interesting with motion" is generated. Following that token, a control code 1 is generated indicating motion to the right. The video encoder therefore need not encode the data values 20 and 21 but merely needs to generate the interesting with motion token followed by the motion to the right control code. When the video encoder proceeds to the two data values block 14 and 15, the video encoder need not send

the "interesting with motion" token but rather only sends the left control code 0. Similarly, when the video encoder proceeds to encode the two data value block 16 and 17, the video encoder only sends the left control code 0. The control codes for octaves 0 and 1 do not denote motion per se but rather denote left or right location above a lower frequency interesting block of the moving edge. This results in the video encoder not having to encode any of the actual data values representing the moved edge in the decomposition of Figure 43.

The one dimensional illustration of Figures 41, 42 and 43 is presented for ease of illustration and explanation. It is to be understood, however, that this method of indicating edge motion is used in conjunction with the above described two dimensional wavelet decomposition such as the two dimensional wavelet decomposition illustrated in Figure 25. The video encoder searches for movement of the data values representing an edge only by searching the nearest neighboring blocks of data values in the old frame. This method can be used to search many neighbors or a few neighbors depending on the application. The counter scheme described in connection with Figures 27 and 28 can be used to determine the locations of those neighboring blocks. Although the edge motion illustrated in connection with Figures 41, 42, and 43 shows the very same data values being moved in the tree structure of the decomposition, it is to be understood that in practice the values of the data values representing the same edge may change slightly with the movement of the edge. The video encoder takes this into account by judging corresponding data values using a motion data value threshold to determine if corresponding data values in fact do represent the same edge. By indicating edge motion and not sending the edge data values themselves it is possible to both increase the compression and also improve the quality of the decompressed image.

SIX COEFFICIENT QUASI-DAUBECHIES FILTERS

The Daubechies six coefficient filters are defined by the six low pass filter coefficients, listed in the table below to 8 decimal places. The coefficients are also defined in terms of four constants, α, β, γ and ϵ, where $\alpha = 0.10588942$, $\beta = -0.54609641$, $\gamma = 2.4254972$ and $\epsilon = 3.0059769$.

	Daubechies coefficients	Alternative representation	Normalized coefficients	Converted Coefficients
a	0.33267055	$1/\epsilon$	0.2352336	$\frac{30}{128}$
b	0.80689151	γ/ϵ	0.57055846	$\frac{73}{128}$
c	0.45987750	$-\beta(\alpha+\gamma)/\epsilon$	0.3251825	$\frac{41}{128}$
-d	-0.13501102	$\beta(1-\alpha\gamma)/\epsilon$	-0.095467208	$\frac{-12}{128}$
-e	-0.08544127	$-\alpha\gamma/\epsilon$	-0.060416101	$\frac{-7}{128}$
f	0.03522629	α/ϵ	0.024908749	$\frac{3}{128}$

Table 4

The coefficients (a, b, c, -d, -e, f) sum to $\sqrt{2}$. The normalized coefficients sum to 1, which gives the filter the property of unity gain, which in terms of the alternative representation is equivalent to a change in the value of ϵ to 4.2510934. These values can be approximated to any given precision by a set of fractions. In the example shown above, each of the normalized values has been multiplied by 128 and rounded appropriately, thus the coefficient a has been converted to $\frac{30}{128}$. Filtering is therefore possible using integer multiplications rather than floating point arithmetic. This greatly reduces implementation cost in terms of digital hardware gate count and computer software speed. The following equations show a single step in the filtering process, the outputs H and G being the low and high pass outputs, respectively:

$$H_1=aD_0+bD_1+cD_2-dD_3-eD_4+fD_5 \qquad \text{(equ. 72)}$$

$$G_1=-fD_0-eD_1+dD_2+cD_3-bD_4+aD_5 \qquad \text{(equ. 73)}$$

H_1 and G_1 are calculated as follows. Each data value D is multiplied by the relevant integer numerator (30, 73, 41, 12, 7, 3) and summed as shown. The values of H and G are found by dividing the summations by the constant 128. Because 128 is an integer power of 2, the division operation requires little digital hardware to implement and only simple arithmetic shift operations to implement in software. The filters H and G are quasi-perfect reconstruction filters:

$$a+b+c-d-e+f=1 \qquad \text{(equ. 74)}$$

$$-f-e+d+c-b+a=0 \qquad \text{(equ. 75)}$$

$$a+c-e=\frac{1}{2} \qquad \text{(equ. 76)}$$

$$f-d+b=\frac{1}{2} \qquad \text{(equ. 77)}$$

Equation 74 guarantees unity gain. Equation 75 guarantees that the high pass filter will generate zero for a constant input signal. Equations 76 and 77 guarantee that an original signal once transferred can be reconstructed exactly.

The following equations show a single step in the inverse transformation:

$$D_2=2(-eH_0-bG_0+cH_1+dG_1+aH_2-fG_2) \qquad \text{(equ. 78)}$$

$$D_3=2(fH_0+aG_0-dH_1+cG_1+bH_2-eG_2) \qquad \text{(equ. 79)}$$

As for the forward filtering process, the interleaved H and G data stream is multiplied by the relevant integer numerator and summed as shown. The output D data values are found by dividing the summations by the constant 64, which is also an integer power of 2.

To calculate the first and last H and G values, the filter equations must be altered such that values outside the boundaries of the data stream are not required. For example, if H_0 is to be calcualted using the six coefficient filter, the values D_{-1} and D_{-2} would be required. Because

these values are not defined, a different filter is used at the beginning and end of the data stream. The new filters are determined such that the reconstruction process for the first and last two data values is possible. The following pair of equations show the filter used to calculate the first H and G values:

$$H_0=cD_0-dD_1-eD_2+fD_3 \quad \text{(equ. 80)}$$

$$G_0=dD_0+cD_1-bD_2+aD_3 \quad \text{(equ. 81)}$$

The last H and G values are calculated with:

$$H_5=aD_8+bD_9+cD_A-dD_B \quad \text{(equ. 82)}$$

$$G_5=fD_8-eD_9+dD_A+cD_B \quad \text{(equ. 83)}$$

In this case, these equations are equivalent to using the non-boundary equations with data values outside the data stream being equal to zero. The following inverse transform boundary filters are used to reconstruct the first two and last two data values:

$$D_0=2\left(\left(c-\frac{b}{\beta}\right)H_0+\left(d+\frac{e}{\beta}\right)G_0+aH_1-fG_1\right) \quad \text{(equ. 84)}$$

$$D_1=2\left(\left(\frac{a}{\beta}-d\right)H_0+\left(c-\frac{f}{\beta}\right)G_0+bH_1-eG_1\right) \quad \text{(equ. 85)}$$

$$D_A=2\left(-eH_4-bG_4+\left(c-\frac{f}{\beta}\right)H_5+\left(d-\frac{a}{\beta}\right)G_5\right) \quad \text{(equ. 86)}$$

$$D_B=2\left(fH_4+aG_4-\left(d+\frac{e}{\beta}\right)H_5+\left(c-\frac{b}{\beta}\right)G_5\right) \quad \text{(equ. 87)}$$

INCREASING SOFTWARE DECOMPRESSION SPEED

A system is desired for compressing and decompressing video using dedicated digital hardware to compress and using software to decompress. For example, in a video mail application one user uses a hardware compression expansion card for an IBM PC personal computer coupled to a video camera to record a video message in the form of a video message file. This compressed video message file is then transmitted via electronic mail over a network such as a hardwired network of an office building. A recipient user receives the compressed video message file as he/she would receive a normal mail file and then uses the software to

decompress the compressed video message file to retrieve the video mail. The video mail may be displayed on the monitor of the recipient's personal computer. It is desirable to be able to decompress in software because decompressing in software frees multiple recipients from purchasing relatively expensive hardware. Software for performing the decompression may, for example, be distributed free of charge to reduce the cost of the composite system.

In one prior art system, the Intel Indeo video compression system, a hardware compression expansion card compresses video and a software package is usable to decompress the compressed video. This system, however, only achieves a small compression ratio. Accordingly, video picture quality will not be able to be improved as standard personal computers increase in computing power and/or video bandwidth.

The specification above discloses a method and apparatus for compressing and decompressing video. The software decompression implementation written in the programming language C disclosed in Appendix A only decompresses at a few frames per second on a standard personal computer at the present date. A method capable of implementation in software which realizes faster decompression is therefore desirable.

A method for decompressing video described above is therefore modified to increase software execution speed. Although the b=19/32, a=11/32, c=5/32 and d=3/32 coefficients used to realize the high and low pass forward transform perfect reconstruction digital filters are used by dedicated hardware to compress in accordance with an above described method, the coefficients b=5/8, a=3/8, c=1/8 and d=1/8 are used to decompress in software on a digital computer. The coefficients are determined as shown in the table below.

$$a = \frac{1+\sqrt{3}}{8} \approx .3415(8) = 2.732 \approx \frac{3}{8}$$
$$b = \frac{3+\sqrt{3}}{8} \approx .5915(8) = 4.732 \approx \frac{5}{8}$$
$$c = \frac{3-\sqrt{3}}{8} \approx .1585(8) = 1.268 \approx \frac{1}{8}$$
$$d = \frac{-1+\sqrt{3}}{8} \approx .0915(8) = 0.732 \approx \frac{1}{8}$$

Table 5

An even start inverse transform digital filter in accordance with the present embodiment is:

$$D_0 = 4[(b-a)H_0 + (c-d)G_0] \qquad \text{(equ. 88)}$$

where, for example, D_0 is a first inverse transformed data value indicative of a corresponding first data value of a row of the original image, and where H_0 and G_0 are first low and high pass component transformed data values of a row of a sub-band decomposition.

An odd end inverse transform digital filter in accordance with the present embodiment is:

$$D_B = 4[(c+d)H_5 - (a+b)G_5] \qquad \text{(equ. 89)}$$

where, for example, D_B is a last inverse transformed data value indicative of a corresponding last data value of a row of the original image, and where H_5 and G_5 are last low and high pass component transformed data values of a row of a sub-band decomposition.

An odd interleaved inverse transform digital filter in accordance with the present embodiment is:

$$\frac{D(2x-1)}{2} = \tfrac{1}{8}H(x-1) - \tfrac{5}{8}G(x-1) + \tfrac{3}{8}H(x) + \tfrac{1}{8}G(x) \qquad \text{(equ. 90)}$$

An even interleaved inverse transform digital filter in accordance with the present embodiment is:

$$\frac{D(2x)}{2} = -\tfrac{1}{8}H(x-1) + \tfrac{3}{8}G(x-1) + \tfrac{5}{8}H(x) + \tfrac{1}{8}G(x) \qquad \text{(equ. 91)}$$

As indicated by equations 90 and 91, the odd and even interleaved inverse transform digital filters operable on

the same H and G values of the sub-band decomposition but generate the odd and even inverse transformed data values in a row between the even start and odd end filters of equations 88 and 89.

Using the above even start, odd end, odd interleaved and even interleaved inverse transform digital filters, a frame rate of approximately 15 frames/second is realizable executing on a Macintosh Quadra personal computer having a 68040 microprocessor. Digital filters using the coefficients b=5/8, a=3/8, c=1/8 and d=1/8 may also be realized in dedicated digital hardware to reduce the cost of a dedicated hardware implementation where a slightly lower compression ratio is acceptable.

To further increase software decompression speed when decompressing video on a digital computer, only two octaves of inverse transform are performed on video which was previously compressed using three octaves of forward transform. This results in the low pass component of the octave 0 decomposition. The low pass component of the octave 0 decomposition is a non-aliased high quality quarter size decimated version of the original image. Rather than performing octave 0 of inverse transform, horizontal linear interpolation is used to expand each row of data values of the low pass component of the octave 0 decomposition into twice the number of data values. To expand the number of rows, each row of interpolated data values is replicated once so that the total number of rows is doubled. In some embodiments, interpolation techniques other than linear interpolation are used to improve image quality. For example, spline interpolation or polynomial interpolation may be used.

To further increase software execution speed when decompressing video, luminance data values are decompressed using the digital filters of equations 88, 89, 90 and 91. The chrominance data values, on the other hand, are decompressed using even and odd interleaved reconstruction filters having a fewer number of coefficients than four.

In one embodiments, two coefficient odd interleaved Haar and even interleaved Haar filters are used. The even interleaved Haar reconstruction filter is:

$$D_0 = (H_0 + G_0) \qquad \text{(equ. 92)}$$

The odd interleaved Haar reconstruction filter is:

$$D_1 = (H_0 - G_0) \qquad \text{(equ. 93)}$$

Because the above Haar filters each only have two coefficients, there is no boundary problem as is addressed in connection with an above-described method. Accordingly, another start inverse transform digital filter and another end inverse transform digital filter are not used.

To increase software execution speed still further when decompressing video, variable-length SEND and STILL_SEND tokens are used. Data values are encoded using a Huffman code as disclosed above whereas tokens are generated in variable-length form and appear in this variable-length form in the compressed data stream. This allows decompression to be performed without first calculating flags.

Figure 44 shows variable-length tokens used for encoding and decoding in accordance with some embodiments of the present invention. Because transitions from SEND mode to STOP mode or from STILL_SEND mode to STOP mode occur most frequently of the transitions indicated in Figure 44, the corresponding tokens consist of only one bit.

In general, if an area changes from white to black in two consecutive frames of a video sequence and if the encoder is in LPF_SEND mode, then the difference between the corresponding data values after quantization will be much larger than 37. 37 is the maximum number encodable using the specific Huffman code set forth in connection with an above-described method. Because such a large

change in data value cannot be encoded, an artifact will be generated in the decompressed image for any change in quantized data values exceeding 37. Accordingly, the Huffman code in the table below is used in accordance with one embodiment of the present invention.

HUFFMAN CODE	qindex
0	0
1s1	±1
1s01	±2
1s001	±3
1s0001	±4
1s00001	±5
1s000001	±6
1s0000001	±7
1s0000000 (|qindex|-8)	±8 . . ±135

Table 6

In Table 6 above, the value (|*qindex*| - 8) is seven bits in length. The s in Table 6 above is a sign bit.

This embodiment is not limited to video mail applications and is not limited to systems using dedicated hardware to compress and software executing on a digital computer to decompress. Digital circuitry of a general purpose digital computer having a microprocessor may be used to decode and inverse transform a compressed image data stream. The coefficients 5/8, 3/8, 1/8 and 1/8 independent of sign may be the four coefficients of four coefficient high and low pass forward transform perfect reconstruction digital filters used to transform image data values into a sub-band decomposition.

Although the present invention has been described by way of the above described specific embodiments, it will be understood that certain adaptations, modifications, rearrangements and combinations of various features of the specific embodiments may be practiced without departing from the scope of the invention. Filters other than the four coefficient quasi-Daubechies filters can be used. In some embodiments, six coefficient quasi-Daubechies filters are used. Embodiments of this invention may, for example, be practiced using a one-dimensional tree structure, a two-dimensional tree structure, or a three-dimensional tree structure. Rather than testing whether or not a two-by-two block of data values is interesting, blocks of other sizes may be used. Three-by-three blocks of data values may, for example, be tested. Blocks of different sizes may be used in different octaves of a decomposition. In certain embodiments, there are different types of interesting blocks. The use of tokens in combination with use of a tree structure of a decomposition to reduce the number of data values encoded may be extended to include other tokens having other meanings. The "interesting with motion" token is but one example. Tree structures may be used in numerous ways to estimate the activity of a frame for rate control purposes. Numerous boundary filters, thresholds, encoder and decoder modes, token schemes, tree traversing address generators, quantization schemes, Huffman-like codes, and rate control schemes will be apparent from the specific embodiments. The above-described specific embodiments are therefore described for instructional purposes only and are not intended to limit the invention as set forth in the appended claims.

DATA COMPRESSION AND DECOMPRESSION

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M-2357 US

APPENDIX A

source/Bits.c

```
/*
        Reading and writing bits from a file
*/

#include        "../include/xwave.h"
#include        "../include/Bits.h"

Bits    bopen(name,mode)

String  name, mode;

{
        Bits    bits=(Bits)MALLOC(sizeof(BitsRec));

        if((bits->fp=fopen(name,mode))==(FILE*)0)Eprintf("Failed to open binary
file\n");       /*change*/
        bits->bufsize=0;        /*new*/
        bits->buf=(unsigned char)0;         /*new*/
        return(bits);
}

void    bclose(bits)

Bits    bits;

{
        if(fclose(bits->fp)!=0) Eprintf("Failed to close binary file\n");  /*was:
fclose(bits->fp)*/
```

```
        XtFree(bits);
}

void    bread(bytes,num,bits)

unsigned char        *bytes;
int     num;
Bits    bits;

{
        int     byte=0, bit=0,pull,b;

        bytes[byte]=0;
        while(num>0) {
                if (bits->bufsize==0) {
                        pull=fgetc(bits->fp);
                        if(pull==EOF)
                                {
                                /*printf("EOF\n");    Previously didn't check for
EOF:bits->buf=(unsigned char)fgetc(bits->fp)*/
                                for(b=byte+1;b<num/8+1;b++)
                                        bytes[b]=(unsigned char)0;
                                return;
                                }
                        bits->buf=(unsigned char)pull;
                        bits->bufsize=8;
                }

bytes[byte]=((1&bits->buf)!=0)?bytes[byte]|(1<<bit):bytes[byte]&~(1<<bit);
                if (bit==7) { bit=0; byte++; bytes[byte]=0; }        /* was bit==8 */
                else bit++;
                bits->buf=bits->buf>>1;
```

```
                bits->bufsize--;
                num--;
        }
}

void    bwrite(bytes,num,bits)

unsigned char           *bytes;
int     num;
Bits    bits;

{
        int     byte=0, bit=0;
        unsigned char           xfer;

        while(num>0) {
                if (bit==0) {
                        xfer=bytes[byte++];
```

source/Color.c

```
/*
 *	Color routines
 */

#include	"../include/xwave.h"
#define	GAMMA	1.0/2.2

int
VisualClass[6]={PseudoColor,DirectColor,TrueColor,StaticColor,GrayScale,StaticGray};

/*	Function Name:	Range
 *	Description:	Range convert for RGB/YUV calculations
 *	Arguments:	old_x - old value (0..old_r-1)
 *			old_r - old range <new_r
 *			new_r - new range
 *	Returns:	old_x scaled up to new range
 */

int	Range(old_x,old_r,new_r)

int	old_x, old_r, new_r;

{
	return((old_x*new_r)/old_r);
}

/*	Function Name:	Gamma
 *	Description:	Range convert with Gamma correction for RGB/YUV calculations
 *	Arguments:	as Range +
 *			factor - gamma correction factor
```

```
 *     Returns:       old_x gamma corrected and scaled up to new range
 */

int     Gamma(old_x,old_r,new_r,factor)

int     old_x, old_r, new_r;
double        factor;

{
        return((int)((double)new_r*pow((double)old_x/(double)old_r,factor)));
}

/*      Function Name:      Dither
 *      Description:  Range convert with dithering for RGB/YUV calculations
 *      Arguments:    levels - output range (0..levels-1)
 *                          pixel - pixel value (0..1<<8+precision-1)
 *                          x, y - dither location
 *                          precision - pixel range (0..1<<8+precision-1)
 *      Returns:      dithered value (0..levels-1)
 */

int     Dither(levels,pixel,x,y,precision)

int     pixel, levels, x, y, precision;

{
        int     bits=8+precision,
                     pixlev=pixel*levels,

value=(pixlev>>bits)+((pixlev-(pixlev&(-1<<bits)))>>precision>global->dither[x
&15][y&15]?1:0);
```

```
	return(value>=levels?levels-1:value);
}


/*	Function Name:	ColCvt
 *	Description:	Converts between RGB and YUV triples
 *	Arguments:	src - source triple
 *			dst - destination triple
 *			rgb_yuv - convert direction RGB->YUV True
 *			max - range of data (max-1..-max)
 *	Returns:	alters dst.
 */

void	ColCvt(src,dst,rgb_yuv,max)

short	src[3], dst[3];
Boolean		rgb_yuv;
int	max;

{
	double		rgb_yuv_mat[2][3][3]={{
		{0.299,0.587,0.114},
		{-0.169,-0.3316,0.5},
		{0.5,-0.4186,-0.0813}
	},{
		{1,0,1.4021},
		{1,-0.3441,-0.7142},
		{1,1.7718,0}
	}};
	int	i, channel;

	for(channel=0;channel<3;channel++) {
```

```
        double      sum=0.0;

        for(i=0;i<3;i++)
sum+=(double)(src[i])*rgb_yuv_mat[rgb_yuv?0:1][channel][i];
        dst[channel]=(int)sum<-max?-max:(int)sum>max-1?max-1:(short)sum;
    }
}

/*  Function Name:   CompositePixel
 *  Description:  Calculates pixel value from components
 *  Arguments:    frame - Frame to be drawn on
 *                      x, y - coordinate of pixel in data
 *                      X, Y - coordinate of pixel in display
 *  Returns:      pixel value in colormap
 */

int    CompositePixel(frame,x,y,X,Y)

Frame frame;
int    x, y, X, Y;

{
    Video  vid=frame->video;
    int    channel=frame->channel, pixel, value=0;

    if (channel!=3) {

pixel=(int)vid->data[channel][frame->frame][Address2(vid,channel,x,y)]+(128<<vid-
>precision);
            value=Dither(global->levels,pixel,X,Y,vid->precision);
    } else for(channel=0;channel<3;channel++) {
            int
```

```
levels=vid->type==RGB?global->rgb_levels:global->yuv_levels[channel];


pixel=(int)vid->data[channel][frame->frame][Address(vid,channel,x,y)]+(128<<vid-
>precision),
            value=levels*value+Dither(levels,pixel,X,Y,vid->precision);
        }
        return(value);
}

void    InitVisual()

{
        Display         *dpy=XtDisplay(global->toplevel);
        int     scrn=XDefaultScreen(dpy), class=0, depth=8, map, i, r, g, b, y, u, v;
        String
VisualNames[6]={"PseudoColor","DirectColor","TrueColor","StaticColor","GrayScale",
"StaticGray"};
        XColor          color;

        global->visinfo=(XVisualInfo *)MALLOC(sizeof(XVisualInfo));
        while(depth>0
&&!XMatchVisualInfo(dpy,scrn,depth,VisualClass[class],global->visinfo))
                if (class==5) {class=0; depth--;} else class++;
        Dprintf("Visual: %s depth %d\n",VisualNames[class],depth);
        global->palettes=(Palette)MALLOC(sizeof(PaletteRec));
        strcpy(global->palettes->name,"Normal");
        global->palettes->next=NULL;
        global->no_pals=1;
        switch(global->visinfo->class) {
        case TrueColor:
        case DirectColor:
```

```
        case StaticColor:
        case GrayScale:
                fprintf(stderr,"Unsupported visual type: %s\n",VisualNames[class]);
                exit();
                break;
        case PseudoColor:
                global->levels=global->visinfo->colormap_size;
                global->rgb_levels=(int)pow((double)global->levels,1.0/3.0);
                for(map=0;map<2;map++) { /* rgb non-gamma and gamma maps */

global->cmaps[map]=XCreateColormap(dpy,XDefaultRootWindow(dpy),global->visinfo
->visual,AllocAll);
                        for(r=0;r<global->rgb_levels;r++)
                                for(g=0;g<global->rgb_levels;g++)
                                        for(b=0;b<global->rgb_levels;b++) {

color.pixel=(r*global->rgb_levels+g)*global->rgb_levels+b;

color.red=(map&1)?Gamma(r,global->rgb_levels,65536,GAMMA):Range(r,global->rg
b_levels,65536);

color.green=(map&1)?Gamma(g,global->rgb_levels,65536,GAMMA):Range(g,global->
rgb_levels,65536);

color.blue=(map&1)?Gamma(b,global->rgb_levels,65536,GAMMA):Range(b,global->r
gb_levels,65536);
                                                color.flags=DoRed | DoGreen | DoBlue;

XStoreColor(dpy,global->cmaps[map],&color);
                                        }
                        color.pixel=global->levels-1;
                        color.red=255<<8;
```

```
            color.green=255<<8;
            color.blue=255<<8;
            color.flags=DoRed | DoGreen | DoBlue;
            XStoreColor(dpy,global->cmaps[map],&color);
        }
        for(map=2;map<4;map++) { /* mono non-gamma and gamma maps */

global->cmaps[map]=XCreateColormap(dpy,XDefaultRootWindow(dpy),global->visinfo
->visual,AllocAll);
            for(i=0;i<global->visinfo->colormap_size;i++) {
                color.pixel=i;

color.red=(map&1)?Gamma(i,global->levels,65536,GAMMA):Range(i,global->levels,6
5536);

color.green=(map&1)?Gamma(i,global->levels,65536,GAMMA):Range(i,global->levels
,65536);

color.blue=(map&1)?Gamma(i,global->levels,65536,GAMMA):Range(i,global->levels,
65536);
                color.flags=DoRed | DoGreen | DoBlue;
                XStoreColor(dpy,global->cmaps[map],&color);
            }
        }
        global->yuv_levels[0]=(int)pow((double)global->levels,1.0/2.0);
        global->yuv_levels[1]=(int)pow((double)global->levels,1.0/4.0);
        global->yuv_levels[2]=(int)pow((double)global->levels,1.0/4.0);
        for(map=4;map<6;map++) { /* yuv non-gamma and gamma maps */

global->cmaps[map]=XCreateColormap(dpy,XDefaultRootWindow(dpy),global->visinfo
->visual,AllocAll);
            for(y=0;y<global->yuv_levels[0];y++)
```

```
for(u=0;u<global->yuv_levels[1];u++)
        for(v=0;v<global->yuv_levels[2];v++) {
                short
src[3]={(short)(Range(y,global->yuv_levels[0],65536)-32768),

(short)(Range(u,global->yuv_levels[1],65536)-32768),

(short)(Range(v,global->yuv_levels[2],65536)-32768)}, dst[3];

                ColCvt(src,dst,False,65536/2);

color.pixel=(y*global->yuv_levels[1]+u)*global->yuv_levels[2]+v;

color.red=(map&1)?Gamma((int)dst[0]+32768,65536,65536,GAMMA):(int)dst[0]+3276
8;

color.green=(map&1)?Gamma((int)dst[1]+32768,65536,65536,GAMMA):(int)dst[1]+32
768;

color.blue=(map&1)?Gamma((int)dst[2]+32768,65536,65536,GAMMA):(int)dst[2]+327
68;
                color.flags=DoRed | DoGreen | DoBlue;

XStoreColor(dpy,global->cmaps[map],&color);
        }
    color.pixel=global->levels-1;
    color.red=255<<8;
    color.green=255<<8;
    color.blue=255<<8;
    color.flags=DoRed | DoGreen | DoBlue;
    XStoreColor(dpy,global->cmaps[map],&color);
}
```

```
            global->palettes->mappings=NULL;
            break;
        case StaticGray:
            global->levels=1<<depth;
            for(i=0;i<6;i++) global->cmaps[i]=XDefaultColormap(dpy,scrn);
            color.pixel=0;
            XQueryColor(dpy,XDefaultColormap(dpy,scrn),&color);
            if (color.red==0 && color.green==0 && color.blue==0)
global->palettes->mappings=NULL;
            else {
                global->palettes->mappings=(Map)MALLOC(sizeof(MapRec));
                global->palettes->mappings->start=0;
                global->palettes->mappings->finish=global->levels-1;
                global->palettes->mappings->m=-1;
                global->palettes->mappings->c=global->levels-1;
                global->palettes->mappings->next=NULL;
            }
            break;
        }
}

Colormap    ChannelCmap(channel,type,gamma)

int     channel;
VideoFormat type;
Boolean     gamma;

{
        Colormap    cmap;

        if (channel!=3 || type==MONO) {
            if (gamma) cmap=global->cmaps[global->cmaps[2]==NULL?3:2];
```

```
        else cmap=global->cmaps[global->cmaps[3]==NULL?2:3];
    } else if (type==RGB) {
        if (gamma) cmap=global->cmaps[global->cmaps[0]==NULL?1:0];
        else cmap=global->cmaps[global->cmaps[1]==NULL?0:1];
    } else {
        if (gamma) cmap=global->cmaps[global->cmaps[4]==NULL?5:4];
        else cmap=global->cmaps[global->cmaps[5]==NULL?4:5];
    }
    return(cmap);
}
```

source/Convert.c

```
#include        "../include/xwave.h"

short   cti(c)

char    c;

{
        return((short)(c)^-128);
}

char    itc(i)

short   i;

{
        static int      errors=0;
        if (i<-128 || i>127) {
                if (errors==99) {
                        Dprintf("100 Conversion overflows\n");
                        errors=0;
                } else errors++;
                i=(i<-128)?-128:127;
        }
        return((char)(i^128));
}
```

source/Convolve3.c

```
/*
        2D wavelet transform convolver (fast hardware emulation)
        New improved wavelet coeffs : 11 19 5 3
*/

#include        "../include/xwave.h"

/*      Function Name:      Round
 *      Description:   Rounding to a fixed number of bits, magnitude rounded down
 *      Arguments:     number - number to be rounded
 *                              bits - shifted bits lost from number
 *      Returns: rounded number
 */

short   Round(number,bits)

int     number;
int     bits;

{
        if (bits==0) return((short)number);
        else return((short)(number+(1<<bits-1)-(number<0?0:1) >> bits));
}

/*      Function Name:      Convolve
 *      Description:   Perform a wavelet convolution on image data
 *      Arguments:     data - data to be transformed
 *                              dirn - convolution direction
```

```
*                       size - size of image data
*                       oct_src, oct_dst - initial and final octave numbers
*   Returns:        data altered
*/


void    Convolve(data,dirn,size,oct_src,oct_dst)

short   *data;
Boolean     dirn;
int     size[2], oct_src, oct_dst;

{
        int     tab[4][4], addr[4]={-1,-1,-1,-1}, index, mode, i, j, oct, orient,
area=size[0]*size[1];
        Boolean     fwd_rev=oct_src<oct_dst;
        int     windows[12][5]={
                {1,2,3,-4,2}, /* 0 - normal forward 0 */
                {4,-3,2,1,3}, /* 1 - normal forward 1 */
                {1,-2,3,4,2}, /* 2 - normal reverse 0 */
                {4,3,2,-1,3}, /* 3 - normal reverse 1 */
                {2,3,4,-4,3}, /* 4 - end forward 0 */
                {4,-4,3,2,4}, /* 5 - end forward 1 */
                {2,2,3,-4,2}, /* 6 - start forward 0 */
                {4,-3,2,2,3}, /* 7 - start forward 1 */
                {3,-4,-4,3,4}, /* 8 - break reverse end dirn==False*/
                {4,3,-3,-4,3}, /* 9 - break reverse start dirn==False */
                {-3,-4,4,3,4}, /* 10 - break reverse end dirn==True */
                {-4,3,3,-4,3}, /* 11 - break reverse start dirn==True */
        }, win[3];                  /* 12 - no calculation */

        for(oct=oct_src;oct!=oct_dst;oct+=(fwd_rev?1:-1)) {
                long    shift=oct-(fwd_rev?0:1);
```

```
for(orient=0;orient<2;orient++) {
        Boolean         x_y=fwd_rev==(orient==0);

for (index=0;index<(area>>(shift<<1));index++) {
        long    major, minor, value, valuex3, valuex11, valuex19, valuex5;

        major=index/(size[x_y?0:1]>>shift);
        minor=index-major*(size[x_y?0:1]>>shift);
        for(j=0;j<3;j++) win[j]=12;
        switch(minor) {
        case 0: break;
        case 1: if (!fwd_rev) win[0]=dirn?11:9; break;
        case 2: if (fwd_rev) { win[0]=6; win[1]=7; }; break;
        default:
                        if (minor+1==size[x_y?0:1]>>shift) {
                                if (fwd_rev) { win[0]=4; win[1]=5; }
                                else { win[0]=2; win[1]=3; win[2]=dirn?10:8; }
                        } else if (fwd_rev) {
                                if ((1&minor)==0) { win[0]=0; win[1]=1; }
                        } else {
                                if ((1&minor)!=0) { win[0]=2; win[1]=3; }
                        }
        }
        addr[3&index]=(x_y?minor:major)+size[0]*(x_y?major:minor)<<shift;
        value=(int)data[addr[3&index]];

        valuex5=value+(value<<2);
        valuex3=value+(value<<1);
        valuex11=valuex3+(value<<3);
        valuex19=valuex3+(value<<4);
        tab[3&index][3]=fwd_rev || !dirn?valuex3:valuex19;
        tab[3&index][2]=fwd_rev || dirn?valuex5:valuex11;
```

```
        tab[3&index][1]=fwd_rev || !dirn?valuex19:valuex3;
        tab[3&index][0]=fwd_rev || dirn?valuex11:valuex5;
        for(j=0;j<3 && win[j]!=12;j++) {
            int     conv=0;

            for(i=0;i<4;i++) {
                int     wave=dirn?3-i:i;


conv+=negif(0>windows[win[j]][wave],tab[3&index+abs(windows[win[j]][i])][wave]);
            }

data[addr[3&index+windows[win[j]][4]]]=Round(conv,fwd_rev?5:win[j]>7?3:4);
        }
    }}}
}
```

source/Copy.c

```
/*
        Copy video, includes direct copy, differencing, LPF zero, LPF only, RGB-YUV
conversion and gamma correction
*/

#include        "../include/xwave.h"
#include        "Copy.h"
extern int      Shift();
extern void     ColCvt();

void    CopyVideoCtrl(w,closure,call_data)

Widget          w;
caddr_t closure, call_data;

{
        CopyCtrl        ctrl=(CopyCtrl)closure;
        Video   new=CopyHeader(ctrl->video), src=ctrl->video;
        int     frame, channel, i, x, y, X, Y, map[256];

        if (global->batch==NULL)
ctrl->mode=(int)XawToggleGetCurrent(ctrl->radioGroup);
        strcpy(new->name,ctrl->name);
        strcpy(new->files,new->name);
        switch(ctrl->mode) {
        case    1:      Dprintf("Direct copy\n");
                                new->UVsample[0]=ctrl->UVsample[0];
                                new->UVsample[1]=ctrl->UVsample[1];
```

```
                        break;
        case    2:      Dprintf("Differences\n");
                        break;
        case    3:      Dprintf("LPF zero\n");
                        break;
        case    4:      Dprintf("LPF only\n");
                        new->trans.type=TRANS_None;

new->size[0]=new->size[0]>>new->trans.wavelet.space[0];

new->size[1]=new->size[1]>>new->trans.wavelet.space[0];
                        break;
        case    5:      Dprintf("RGB-YUV\n");
                        new->type=new->type==YUV?RGB:YUV;
                        new->UVsample[0]=0;
                        new->UVsample[1]=0;
                        break;
        case    6:      Dprintf("Gamma conversion\n");
                        new->gamma= !new->gamma;
                        for(i=0;i<256;i++)
map[i]=gamma(i,256,new->gamma?0.5:2.0);
                        break;
        }
        if (new->disk==True) SaveHeader(new);
        for(frame=0;frame<new->size[2];frame++) {
                GetFrame(src,frame);
                NewFrame(new,frame);
                switch(ctrl->mode) {
                case    1:
for(channel=0;channel<(new->type==MONO?1:3);channel++) {
                                int     size=Size(new,channel,0)*Size(new,channel,1);
```

```
                    for(y=0;y<Size(new,channel,1);y++)
                        for(x=0;x<Size(new,channel,0);x++)

new->data[channel][frame][x+Size(new,channel,0)*y]=src->data[channel][frame][Shift(
x,src->type==YUV &&
channel!=0?new->UVsample[0]-src->UVsample[0]:0)+Size(src,channel,0)*Shift(y,src-
>type==YUV && channel!=0?new->UVsample[1]-src->UVsample[1]:0)];
                }
                break;
        case    2:
for(channel=0;channel<(new->type==MONO?1:3);channel++) {
                    int
size=Size(new,channel,0)*Size(new,channel,1);

                    for(i=0;i<size;i++)
new->data[channel][frame][i]=src->data[channel][frame][i]-(frame==0?0:src->data[ch
annel][frame-1][i]);
                    }
                break;
        case    3:
for(channel=0;channel<(new->type==MONO?1:3);channel++) {
                    int
size=Size(new,channel,0)*Size(new,channel,1);

                    for(i=0;i<size;i++) {
                        x=i%Size(new,channel,0);
y=i/Size(new,channel,0);
                        if
(x%(1<<new->trans.wavelet.space[new->type==YUV && channel!=0?1:0])==0
&& y%(1<<new->trans.wavelet.space[new->type==YUV &&
channel!=0?1:0])==0)
```

```
new->data[channel][frame][i]=0;
                                        else
new->data[channel][frame][i]=src->data[channel][frame][i];
                                    }
                                }
                                break;
                case    4:
for(channel=0;channel<(new->type==MONO?1:3);channel++) {
                                    int
size=Size(new,channel,0)*Size(new,channel,1);

                                    for(i=0;i<size;i++) {
                                        x=i%Size(new,channel,0);
y=i/Size(new,channel,0);

new->data[channel][frame][i]=src->data[channel][frame][(x+(y<<new->trans.wavele
t.space[0])*Size(new,channel,0))<<new->trans.wavelet.space[0]];
                                    }
                                }
                                break;
                case    5:      for(X=0;X<new->size[0];X++)
for(Y=0;Y<new->size[1];Y++) {
                                    short   src_triple[3], dst_triple[3];

                                    for(channel=0;channel<3;channel++)

src_triple[channel]=src->data[channel][frame][Address(src,channel,X,Y)];

ColCvt(src_triple,dst_triple,new->type==YUV,1<<7+new->precision);
                                    for(channel=0;channel<3;channel++)
                                        new->data[channel][frame][Address(new,channel,X,Y)]=dst_triple[channel];
                                }
```

```
                        break;
            case    6:
for(channel=0;channel<(new->type==MONO?1:3);channel++) {
                                    int
size=Size(new,channel,0)*Size(new,channel,1);

                                    for(i=0;i<size;i++)
new->data[channel][frame][i]=map[src->data[channel][frame][i]+128]-128;
                        }
                        break;
                }
            if (frame>0) FreeFrame(src,frame-1);
            SaveFrame(new,frame);
            FreeFrame(new,frame);
        }
        FreeFrame(src,src->size[2]-1);
        new->next=global->videos;
        global->videos=new;
}

void    BatchCopyCtrl(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        CopyCtrl        ctrl=(CopyCtrl)closure;

        if (ctrl->video==NULL)
ctrl->video=FindVideo(ctrl->src_name,global->videos);
        CopyVideoCtrl(w,closure,call_data);
}
```

```
CopyCtrl    InitCopyCtrl(name)

String  name;

{
        CopyCtrl    ctrl=(CopyCtrl)MALLOC(sizeof(CopyCtrlRec));

        strcpy(ctrl->src_name,name);
        strcpy(ctrl->name,name);
        ctrl->mode=1;
        return(ctrl);
}

#define     COPY_ICONS      17

void  CopyVideo(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        Video  video=(Video)closure;
        CopyCtrl    ctrl=InitCopyCtrl(video->name);
        NumInput    UVinputs=(NumInput)MALLOC(2*sizeof(NumInputRec));
        Message     msg=NewMessage(ctrl->name,NAME_LEN);
        XtCallbackRec      destroy_call[]={
                {Free,(caddr_t)ctrl},
                {Free,(caddr_t)UVinputs},
                {CloseMessage,(caddr_t)msg},
                {NULL,NULL},
        };
        Widget      shell=ShellWidget("copy_video",w,SW_below,NULL,destroy_call),
```

```
                form=FormatWidget("cpy_form",shell), widgets[COPY_ICONS];
    FormItem    items[]={
        {"cpy_cancel","cancel",0,0,FW_icon,NULL},
        {"cpy_confirm","confirm",1,0,FW_icon,NULL},
        {"cpy_title","Copy a video",2,0,FW_label,NULL},
        {"cpy_vid_lab","Video Name:",0,3,FW_label,NULL},
        {"cpy_text",NULL,4,3,FW_text,(String)msg},

        {"cpy_copy","copy",0,5,FW_toggle,NULL},
        {"cpy_diff","diff",6,5,FW_toggle,(String)6},
        {"cpy_lpf_zero","lpf_zero",7,5,FW_toggle,(String)7},
        {"cpy_lpf_only","lpf_only",8,5,FW_toggle,(String)8},
        {"cpy_color","color_space",9,5,FW_toggle,(String)9},

        {"cpy_gamma","gamma",10,5,FW_toggle,(String)10},
        {"cpy_UV0_int",NULL,0,6,FW_integer,(String)&UVinputs[0]},
        {"cpy_UV0_down",NULL,12,6,FW_down,(String)&UVinputs[0]},
        {"cpy_UV0_up",NULL,13,6,FW_up,(String)&UVinputs[0]},
        {"cpy_UV1_int",NULL,0,14,FW_integer,(String)&UVinputs[1]},

        {"cpy_UV1_down",NULL,12,14,FW_down,(String)&UVinputs[1]},
        {"cpy_UV1_up",NULL,16,14,FW_up,(String)&UVinputs[1]},
    };
    XtCallbackRec       callbacks[]={
        {Destroy,(caddr_t)shell},
        {NULL,NULL},
        {CopyVideoCtrl,(caddr_t)ctrl},
        {Destroy,(caddr_t)shell},
        {NULL,NULL},
        {NULL,NULL}, {NULL,NULL}, {NULL,NULL}, {NULL,NULL},
{NULL,NULL}, {NULL,NULL},
        {NumIncDec,(caddr_t)&UVinputs[0]}, {NULL,NULL},
```

```
        {NumIncDec,(caddr_t)&UVinputs[0]}, {NULL,NULL},
        {NumIncDec,(caddr_t)&UVinputs[1]}, {NULL,NULL},
        {NumIncDec,(caddr_t)&UVinputs[1]}, {NULL,NULL},
    };

    Dprintf("CopyVideo\n");

    msg->rows=1; msg->cols=NAME_LEN;
    ctrl->video=video;
    UVinputs[0].format="UV sub-sample X: %d";
    UVinputs[0].min=0;
    UVinputs[0].max=2;
    UVinputs[0].value= &ctrl->UVsample[0];
    UVinputs[1].format="UV sub-sample Y: %d";
    UVinputs[1].min=0;
    UVinputs[1].max=2;
    UVinputs[1].value= &ctrl->UVsample[1];

    ctrl->UVsample[0]=video->UVsample[0];
    ctrl->UVsample[1]=video->UVsample[1];
    FillForm(form,COPY_ICONS,items,widgets,callbacks);
    ctrl->radioGroup=widgets[5];
    XtSetSensitive(widgets[6],video->size[2]>1);
    XtSetSensitive(widgets[7],video->trans.type!=TRANS_None);
    XtSetSensitive(widgets[8],video->trans.type!=TRANS_None);
    XtSetSensitive(widgets[9],video->type!=MONO);
    XtSetSensitive(widgets[10],video->type!=YUV &&
video->trans.type==TRANS_None);
    XtPopup(shell,XtGrabExclusive);
};
```

source/Frame.c

```
/*
	Frame callback routines for Destroy
*/

#include	"../include/xwave.h"
#include	<X11/Xmu/SysUtil.h>
#include	<pwd.h>
extern void	CvtIndex();
extern Palette		FindPalette();
extern void	SetSensitive();

typedef		struct {
	Frame frame;
	int	frame_number, frame_zoom, frame_palette, frame_channel;
} ExamCtrlRec, *ExamCtrl;

void	FrameDestroy(w,closure,call_data)

Widget		w;
caddr_t		closure, call_data;

{
	Frame frame=(Frame)closure;
	void	CleanUpPoints(), FrameDelete();

	Dprintf("FrameDestroy\n");
	frame->point->usage--;
	if (frame->msg!=NULL) {
```

```
            frame->msg->shell=NULL;
            CloseMessage(NULL,(caddr_t)frame->msg,NULL);
        }
        if (frame->point->usage==0) CleanUpPoints(&global->points);
        XtPopdown(frame->shell);
        XtDestroyWidget(frame->shell);
        FrameDelete(&global->frames,frame);
}

void    CleanUpPoints(points)

Point   *points;

{
        Point   dummy=*points;

        if (dummy!=NULL) {
                if (dummy->usage<1) {
                        *points=dummy->next;
                        XtFree(dummy);
                        CleanUpPoints(points);
                } else CleanUpPoints(&((*points)->next));
        };
}

void    FrameDelete(frames,frame)

Frame *frames, frame;

{
        if      (*frames!=NULL) {
                if (*frames==frame) {
```

```
			int	number=frame->frame;

			frame->frame=-1;
			FreeFrame(frame->video,number);
			*frames=frame->next;
			XtFree(frame);
		} else FrameDelete(&(*frames)->next,frame);
	}
}

void	ExamineCtrl(w,closure,call_data)

Widget		w;
caddr_t		closure, call_data;

{
	ExamCtrl	ctrl=(ExamCtrl)closure;
	Arg	args[1];

	if (ctrl->frame->frame!=ctrl->frame_number-ctrl->frame->video->start) {
		int	old_frame=ctrl->frame->frame;

		ctrl->frame->frame=ctrl->frame_number-ctrl->frame->video->start;
		FreeFrame(ctrl->frame->video,old_frame);
		GetFrame(ctrl->frame->video,ctrl->frame->frame);
	}
	ctrl->frame->zoom=ctrl->frame_zoom;
	ctrl->frame->palette=ctrl->frame_palette;
	ctrl->frame->channel=ctrl->frame_channel;
	XtSetArg(args[0],XtNbitmap,UpdateImage(ctrl->frame));
	XtSetValues(ctrl->frame->image_widget,args,ONE);
```

```
XtSetArg(args[0],XtNcolormap,ChannelCmap(ctrl->frame->channel,ctrl->frame->vide
o->type,ctrl->frame->video->gamma));
        XtSetValues(ctrl->frame->shell,args,ONE);
        if (ctrl->frame->msg!=NULL) UpdateInfo(ctrl->frame);
}

#define         EXAM_ICONS      13

void    Examine(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;

{
        ExamCtrl        ctrl=(ExamCtrl)MALLOC(sizeof(ExamCtrlRec));
        NumInput        num_inputs=(NumInput)MALLOC(2*sizeof(NumInputRec));
        XtCallbackRec destroy_call[]={
                {Free,(caddr_t)ctrl},
                {Free,(caddr_t)num_inputs},
                {NULL,NULL},
        }, pal_call[2*global->no_pals];
        Widget          shell=ShellWidget("examine",w,SW_below,NULL,destroy_call),
                        form=FormatWidget("exam_form",shell), widgets[EXAM_ICONS],
                        pal_widgets[global->no_pals], pal_shell;
        Frame frame=(Frame)closure;
        FormItem        items[]={
                {"exam_cancel","cancel",0,0,FW_icon,NULL},
                {"exam_confirm","confirm",1,0,FW_icon,NULL},
                {"exam_label","Examine",2,0,FW_label,NULL},
                {"exam_ch_lab","Channel :",0,3,FW_label,NULL},

{"exam_ch_btn",ChannelName[frame->video->type][frame->channel],4,3,FW_button,"
```

```
exam_cng_ch"},
            {"exam_pal_lab","Palette :",0,4,FW_label,NULL},

{"exam_pal_btn",FindPalette(global->palettes,frame->palette)->name,4,4,FW_button,"
exam_cng_pal"},
            {"exam_z_int",NULL,0,6,FW_integer,(String)&num_inputs[0]},
            {"exam_z_dowm",NULL,8,6,FW_down,(String)&num_inputs[0]},
            {"exam_z_up",NULL,9,6,FW_up,(String)&num_inputs[0]},
            {"exam_zoom_int",NULL,0,8,FW_integer,(String)&num_inputs[1]},
            {"exam_zoom_dowm",NULL,8,8,FW_down,(String)&num_inputs[1]},
            {"exam_zoom_up",NULL,12,8,FW_up,(String)&num_inputs[1]},
    };
    MenuItem      pal_menu[global->no_pals];
    XtCallbackRec     callbacks[]={
            {Destroy,(caddr_t)shell},
            {NULL,NULL},
            {ExamineCtrl,(caddr_t)ctrl},
            {Destroy,(caddr_t)shell},
            {NULL,NULL},
            {NumIncDec,(caddr_t)&num_inputs[0]}, {NULL,NULL},
            {NumIncDec,(caddr_t)&num_inputs[0]}, {NULL,NULL},
            {NumIncDec,(caddr_t)&num_inputs[1]}, {NULL,NULL},
            {NumIncDec,(caddr_t)&num_inputs[1]}, {NULL,NULL},
    };
    int     i, width=0;
    Palette       pal=global->palettes;
    XFontStruct   *font;
    Arg     args[1];
    caddr_t             dummy[global->no_pals], dummy2[global->no_pals]; /*
gcc-mc68020 bug avoidance */

    Dprintf("Examine\n");
```

```
ctrl->frame=frame;
ctrl->frame_number=frame->frame+frame->video->start;
ctrl->frame_zoom=frame->zoom;
ctrl->frame_palette=frame->palette;
ctrl->frame_channel=frame->channel;
num_inputs[0].format="Frame: %03d";
num_inputs[0].max=frame->video->start+frame->video->size[2]-1;
num_inputs[0].min=frame->video->start;
num_inputs[0].value=&ctrl->frame_number;
num_inputs[1].format="Zoom: %d";
num_inputs[1].max=4;
num_inputs[1].min=0;
num_inputs[1].value=&ctrl->frame_zoom;

FillForm(form,EXAM_ICONS,items,widgets,callbacks);

font=FindFont(widgets[6]);
for(i=0;pal!=NULL;pal=pal->next,i++) {
        pal_menu[i].name=pal->name;
        pal_menu[i].widgetClass=smeBSBObjectClass;
        pal_menu[i].label=pal->name;
        pal_menu[i].hook=NULL;
        pal_call[i*2].callback=SimpleMenu;
        pal_call[i*2].closure=(caddr_t)&ctrl->frame_palette;
        pal_call[i*2+1].callback=NULL;
        pal_call[i*2+1].closure=NULL;
        width=TextWidth(width,pal->name,font);
}
pal_shell=ShellWidget("exam_cng_pal",shell,SW_menu,NULL,NULL);
FillMenu(pal_shell,global->no_pals,pal_menu,pal_widgets,pal_call);
XtSetArg(args[0],XtNwidth,2+width);
XtSetValues(widgets[6],args,ONE);
```

```
if (frame->video->type==MONO) XtSetSensitive(widgets[4],False);
else {
        MenuItem     ch_menu[4];
        Widget
ch_shell=ShellWidget("exam_cng_ch",shell,SW_menu,NULL,NULL), ch_widgets[4];
        XtCallbackRec       ch_call[8];

        font=FindFont(widgets[4]);
        width=0;
        for(i=0;i<4;i++) {
                ch_menu[i].name=ChannelName[frame->video->type][i];
                ch_menu[i].widgetClass=smeBSBObjectClass;
                ch_menu[i].label=ChannelName[frame->video->type][i];
                ch_menu[i].hook=(caddr_t)&ctrl->frame_channel;
                ch_call[i*2].callback=SimpleMenu;
                ch_call[i*2].closure=(caddr_t)&ctrl->frame_channel;
                ch_call[i*2+1].callback=NULL;
                ch_call[i*2+1].closure=NULL;

width=TextWidth(width,ChannelName[frame->video->type][i],font);
        }
        FillMenu(ch_shell,4,ch_menu,ch_widgets,ch_call);
        XtSetArg(args[0],XtNwidth,2+width);
        XtSetValues(widgets[4],args,ONE);
    }
    XtPopup(shell,XtGrabExclusive);
}

void    FramePointYN(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;
```

```
{
        Frame   frame=(Frame)closure;
        Arg     args[1];
        Pixmap          pixmap;
        Display         *dpy=XtDisplay(global->toplevel);
        Icon    point_y=FindIcon("point_y"),
                        point_n=FindIcon("point_n");

        Dprintf("FramePointYN\n");
        frame->point_switch=!frame->point_switch;
        XtSetSensitive(frame->image_widget,frame->point_switch);
        XtSetArg(args[0],XtNbitmap,(frame->point_switch?point_y:point_n)->pixmap);
        XtSetValues(w,args,ONE);
        XtSetArg(args[0],XtNbitmap,&pixmap);
        XtGetValues(frame->image_widget,args,ONE);
        UpdatePoint(dpy,frame,pixmap);
        XtSetArg(args[0],XtNbitmap,pixmap);
        XtSetValues(frame->image_widget,args,ONE);
        if (frame->msg!=NULL) UpdateInfo(frame);
}

void    NewPoint(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;

{
        Frame frame=(Frame)closure;
        Video vid=frame->video;
        void    UpdateFrames();
        int     *posn=(int *)call_data,
channel=frame->channel==3?0:frame->channel;
```

```
        posn[0]=posn[0]>>frame->zoom; posn[1]=posn[1]>>frame->zoom;
        if (vid->trans.type==TRANS_Wave) {
                int     octs=vid->trans.wavelet.space[vid->type==YUV &&
channel!=0?1:0], oct;


CvtIndex(posn[0],posn[1],Size(vid,channel,0),Size(vid,channel,1),octs,&posn[0],&posn[1]
,&oct);
        }
        if (vid->type==YUV && channel!=0) {
                posn[0]=posn[0]<<vid->UVsample[0];
                posn[1]=posn[1]<<vid->UVsample[1];
        }
        Dprintf("NewPoint %d %d previous %d
%d\n",posn[0],posn[1],frame->point->location[0],frame->point->location[1]);
        if (posn[0]!=frame->point->location[0] ||
posn[1]!=frame->point->location[1]) {
                UpdateFrames(global->frames,frame->point,False);
                frame->point->location[0]=posn[0];
                frame->point->location[1]=posn[1];
                UpdateFrames(global->frames,frame->point,True);
        } else Dprintf("No movement\n");
}

void    UpdateFrames(frame,point,update)

Frame frame;
Point   point;
Boolean         update;

{
        Arg     args[1];
```

```
        if (frame!=NULL) {
                if (point==frame->point && frame->point_switch==True) {
                        Pixmap          pixmap;
                        Display         *dpy=XtDisplay(global->toplevel);

                        XtSetArg(args[0],XtNbitmap,&pixmap);
                        XtGetValues(frame->image_widget,args,ONE);
                        UpdatePoint(dpy,frame,pixmap);
                        if (update==True) {
                                XtSetArg(args[0],XtNbitmap,pixmap);
                                XtSetValues(frame->image_widget,args,ONE);
                                if (frame->msg!=NULL) UpdateInfo(frame);
                        }
                }
                UpdateFrames(frame->next,point,update);
        }
}

void    CloseInfo(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;

{
        Frame frame=(Frame)closure;

        frame->msg=NULL;
}

#define         INFO_ICONS          2

void    FrameInfo(w,closure,call_data)
```

```
Widget      w;
caddr_t     closure, call_data;

{
    Frame frame=(Frame)closure;
    Message     msg=NewMessage(NULL,1000);
    XtCallbackRec     callbacks[]={
        {SetSensitive,(caddr_t)w},
        {CloseInfo,(caddr_t)frame},
        {CloseMessage,(caddr_t)msg},
        {NULL,NULL},
    };
    Dprintf("FrameInfo\n");
    frame->msg=msg;
    UpdateInfo(frame);
    TextSize(msg);
    MessageWindow(w,msg,frame->video->name,True,callbacks);
    XtSetSensitive(w,False);
}

void   FrameMerge(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
    Frame frame=(Frame)closure;
    void   MergePoints();
    Arg    args[1];

    Dprintf("FrameMerge\n");
    MergePoints(global->frames,frame);
```

```
}

void    MergePoints(frame_search,frame_found)

Frame frame_search, frame_found;

{
        Arg     args[1];

        if (frame_search!=NULL) {
                if (NULL==XawToggleGetCurrent(frame_search->point_merge_widget)
|| frame_search==frame_found)
                        MergePoints(frame_search->next,frame_found);
                else {
                        Pixmap          pixmap;
                        Display         *dpy=XtDisplay(global->toplevel);

                        XtSetArg(args[0],XtNbitmap,&pixmap);
                        XtGetValues(frame_found->image_widget,args,ONE);
                        if (frame_found->point_switch==True)
UpdatePoint(dpy,frame_found,pixmap);
                        frame_search->point->usage++;
                        frame_found->point->usage--;
                        if (frame_found->point->usage==0)
CleanUpPoints(&global->points);
                        frame_found->point=frame_search->point;
                        if (frame_found->point_switch==True) {
                                UpdatePoint(dpy,frame_found,pixmap);
                                XtSetArg(args[0],XtNbitmap,pixmap);
                                XtSetValues(frame_found->image_widget,args,ONE);
                        }
                        if (frame_found->msg!=NULL) UpdateInfo(frame_found);
```

```
                XawToggleUnsetCurrent(frame_search->point_merge_widget);
                XawToggleUnsetCurrent(frame_found->point_merge_widget);
            }
        }
}

#define     POST_DIR    "postscript"

void  PostScript(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        Frame frame=(Frame)closure;
        Video video=frame->video;
        FILE  *fp, *fopen();
        char  file_name[STRLEN], hostname[STRLEN];
        int   x, y, width=Size(video,frame->channel,0),
height=Size(video,frame->channel,1);
        struct passwd *pswd;
        long  clock;

        Dprintf("PostScript\n");
        sprintf(file_name,"%s%s/%s.ps\0",global->home,POST_DIR,video->name);
        fp=fopen(file_name,"w");
        fprintf(fp,"%%!PS-Adobe-1.0\n");
        pswd = getpwuid (getuid ());
        (void) XmuGetHostname (hostname, sizeof hostname);
        fprintf(fp,"%%%%Creator: %s:%s (%s)\n", hostname,pswd->pw_name,
pswd->pw_gecos);
        fprintf(fp,"%%%%Title: %s\n",video->name);
```

```
        fprintf(fp,"%%%%BoundingBox: 0 0 %d %d\n",width,height);
        fprintf(fp,"%%%%CreationDate: %s",(time (&clock), ctime (&clock)));
        fprintf(fp,"%%%%EndComments\n");
        fprintf(fp,"%d %d scale\n",width,height);
        fprintf(fp,"%d %d 8 image_print\n",width,height);
        GetFrame(video,frame->frame);
        for(y=0;y<height;y++) {
                for(x=0;x<width;x++) {
                        int     X, Y, oct, data;

                        if (video->trans.type==TRANS_Wave) {

CvtIndex(x,y,width,height,video->trans.wavelet.space[0],&X,&Y,&oct);

data=128+Round(video->data[frame->channel%3][frame->frame][Y*video->size[0]+
X]*(oct==video->trans.wavelet.space[0]?1:4),video->precision);
                        } else
data=128+Round(video->data[frame->channel%3][frame->frame][y*video->size[0]+
x],video->precision);
                        fprintf(fp,"%02x",data<0?0:data>255?255:data);
                }
                fprintf(fp,"\n");
        }
        FreeFrame(video,frame->frame);
        fclose(fp);
}

void    Spectrum(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;
```

```
{
        Frame frame=(Frame)closure;
        Display      *dpy=XtDisplay(global->toplevel);
        XColor       xcolor[2], falsecolor;
        int     i;
        Colormap
cmap=ChannelCmap(frame->channel,frame->video->type,frame->video->gamma);

        Dprintf("Spectrum\n");
        falsecolor.flags=DoRed|DoGreen|DoBlue;
        XSynchronize(dpy,True);
        for(i=0;i<2+global->levels;i++) {
                if (i>1) XStoreColor(dpy,cmap,&xcolor[i&1]); /* Restore old color */
                if (i<global->levels) {
                        xcolor[i&1].pixel=i;
                        XQueryColor(dpy,cmap,&xcolor[i&1]);
                        falsecolor.pixel=i;
                        falsecolor.red=xcolor[i&1].red+32512;
                        falsecolor.green=xcolor[i&1].green+32512;
                        falsecolor.blue=xcolor[i&1].blue+32512;
                        XStoreColor(dpy,cmap,&falsecolor);
                }
        }
        XSynchronize(dpy,False);
}
```

source/icon3.c

```
/*
        Create Icons/Menus and set Callbacks
*/

#include        "../include/xwave.h"

/*      Function Name:      FindIcon
 *      Description:   Finds IconRec entry from name in global icon array
 *      Arguments:     icon_name - name of icon bitmap
 *      Returns:       pointer to IconRec with the same name as icon_name
 */

Icon    FindIcon(icon_name)

String  icon_name;

{
        int     i;
        Icon    icon=NULL;

        for (i=0;i<global->no_icons;i++)
                if (!strcmp(global->icons[i].name,icon_name)) icon=&global->icons[i];
        return(icon);
}

void    FillForm(parent,number,items,widgets,callbacks)

int     number;
```

```
FormItem       items[];
Widget         parent, widgets[];
XtCallbackRec         callbacks[];

{
        Arg     args[10];
        int     i, call_i=0;

        for(i=0;i<number;i++) {
                int     argc=0, *view=(int *)items[i].hook;
                char    text[STRLEN];
                float   top;
                NumInput      num=(NumInput)items[i].hook;
                FloatInput    flt=(FloatInput)items[i].hook;
                Message       msg=(Message)items[i].hook;
                WidgetClass
class[15]={labelWidgetClass,commandWidgetClass,commandWidgetClass,asciiTextWidge
tClass,

menuButtonWidgetClass,menuButtonWidgetClass,viewportWidgetClass,toggleWidgetClass
,

commandWidgetClass,commandWidgetClass,commandWidgetClass,labelWidgetClass,
                        scrollbarWidgetClass,labelWidgetClass,formWidgetClass};
                Boolean
call[15]={False,True,True,False,False,False,False,True,True,True,True,False,False,Fals
e,False};

                if (items[i].fromHoriz!=0) {
                        XtSetArg(args[argc],XtNfromHoriz,widgets[items[i].fromHoriz-1]);
argc++;
                }
```

```
if (items[i].fromVert!=0) {
        XtSetArg(args[argc],XtNfromVert,widgets[items[i].fromVert-1]);
argc++;
}
switch(items[i].type) { /* Initialise contents */
case FW_yn:
        items[i].contents=*(Boolean *)items[i].hook?"confirm":"cancel";
        break;
case FW_up:
        items[i].contents="up";
        break;
case FW_down:
        items[i].contents="down";
        break;
case FW_integer:
        sprintf(text,num->format,*num->value);
        items[i].contents=text;
        break;
case FW_float:
        sprintf(text,flt->format,*flt->value);
        items[i].contents=text;
        break;
}
switch(items[i].type) { /* Set contents */
case FW_label: case FW_command: case FW_button: case FW_integer:
case FW_float:
        XtSetArg(args[argc],XtNlabel,items[i].contents); argc++;
        break;
case FW_down: case FW_up: case FW_yn: case FW_toggle: case
FW_icon: case FW_icon_button: {
        Icon    icon=FindIcon(items[i].contents);
```

```
            if (icon==NULL) {
                XtSetArg(args[argc],XtNlabel,items[i].contents); argc++;
            } else {
                XtSetArg(args[argc],XtNbitmap,icon->pixmap); argc++;
                XtSetArg(args[argc],XtNheight,icon->height+2); argc++;
                XtSetArg(args[argc],XtNwidth,icon->width+2); argc++;
            }
            } break;
        }
        switch(items[i].type) { /* Individual set-ups */
        case FW_text:
            XtSetArg(args[argc],XtNstring,msg->info.ptr); argc++;
            XtSetArg(args[argc],XtNeditType,msg->edit); argc++;
            XtSetArg(args[argc],XtNuseStringInPlace,True); argc++;
            XtSetArg(args[argc],XtNlength,msg->size); argc++;
            break;
        case FW_button: case FW_icon_button:
            XtSetArg(args[argc],XtNmenuName,(String)items[i].hook);
argc++;
            break;
        case FW_toggle:
            if ((int)items[i].hook==0) {
                XtSetArg(args[argc],XtNradioData,1); argc++;
            } else {
                caddr_t radioData;
                Arg     radioargs[1];
                Widget      radioGroup=widgets[(int)items[i].hook-1];

                XtSetArg(radioargs[0],XtNradioData,&radioData);
                XtGetValues(radioGroup,radioargs,ONE);

XtSetArg(args[argc],XtNradioData,(caddr_t)((int)radioData+1)); argc++;
```

```
            XtSetArg(args[argc],XtNradioGroup,radioGroup); argc++;
        }
        break;
    case FW_scroll:
        top=(float)(*flt->value-flt->min)/(flt->max-flt->min);
        XtSetArg(args[argc],XtNtopOfThumb,&top); argc++;
        XtSetArg(args[argc],XtNjumpProc,&callbacks[call_i]); argc++;
        while(callbacks[call_i].callback!=NULL) call_i++;
            call_i++;
        break;
    case FW_view:
        if (view!=NULL) {
            XtSetArg(args[argc],XtNwidth,view[0]); argc++;
            XtSetArg(args[argc],XtNheight,view[1]); argc++;
        }
        break;
    }

widgets[i]=XtCreateManagedWidget(items[i].name,class[(int)items[i].type],parent,args,ar
gc);
    switch(items[i].type) { /* Post processing */
    case FW_toggle:
        if (items[i].hook==NULL) { /* Avoids Xaw bug */
            XtSetArg(args[0],XtNradioGroup,widgets[i]);
            XtSetValues(widgets[i],args,ONE);
        }
        break;
    case FW_text: {
        XFontStruct   *font;
        Arg     text_args[1];

        msg->widget=widgets[i];
```

```
XawTextDisplayCaret(msg->widget,msg->edit!=XawtextRead);
XtSetArg(text_args[0],XtNfont,&font);
XtGetValues(widgets[i],text_args,ONE);
argc=0;
if (msg->edit==XawtextRead && msg->info.ptr[0]!='\0')
XtSetArg(args[argc],XtNwidth,4+TextWidth(0,msg->info.ptr,font));
else
XtSetArg(args[argc],XtNwidth,4+msg->cols*(font->max_bounds.width+font->min_bo
unds.width)/2);
argc++;

XtSetArg(args[argc],XtNheight,1+msg->rows*(font->max_bounds.ascent+font->max_
bounds.descent)); argc++;
XtSetValues(widgets[i],args,argc);
} break;
case FW_button:

XtOverrideTranslations(widgets[i],XtParseTranslationTable("<BtnDown>: reset()
NameButton() PopupMenu()"));
break;
case FW_down:
if (*num->value==num->min) XtSetSensitive(widgets[i],False);
num->widgets[0]=widgets[i];
break;
case FW_up:
if (*num->value==num->max) XtSetSensitive(widgets[i],False);
num->widgets[1]=widgets[i];
break;
case FW_integer:
num->widgets[2]=widgets[i];
break;
case FW_scroll:
```

```
                flt->widgets[1]=widgets[i];
                XawScrollbarSetThumb(widgets[i],top,0.05);
                break;
            case FW_float:
                flt->widgets[0]=widgets[i];
                break;
            }
            if (call[(int)items[i].type]) { /* Add Callbacks */
                if (callbacks[call_i].callback!=NULL)
                    XtAddCallbacks(widgets[i],XtNcallback,&callbacks[call_i]);
                while(callbacks[call_i].callback!=NULL) call_i++;
                call_i++;
            }
        }
}

Widget      ShellWidget(name,parent,type,cmap,callbacks)

String name;
Widget      parent;
ShellWidgetType     type;
Colormap    cmap;
XtCallbackRec       callbacks[];

{
        Widget      shell;
        Arg     args[3];
        Position        x, y;
        Dimension       height=-2;
        int     argc=0;
        WidgetClass
class[]={transientShellWidgetClass,transientShellWidgetClass,topLevelShellWidgetClass,p
```

```
ullRightMenuWidgetClass};

        if (type==SW_below || type==SW_over) {
                XtTranslateCoords(parent,0,0,&x,&y);
                if (type==SW_below) {
                        XtSetArg(args[0],XtNheight,&height);
                        XtGetValues(parent,args,ONE);
                }
                XtSetArg(args[argc],XtNx,x); argc++;
                XtSetArg(args[argc],XtNy,y+height+2); argc++;
        }
        if (cmap!=NULL) {
                XtSetArg(args[argc],XtNcolormap,cmap); argc++;
        }
        shell=XtCreatePopupShell(name,class[type],parent,args,argc);
        if (callbacks!=NULL) XtAddCallbacks(shell,XtNdestroyCallback,callbacks);
        return(shell);
}

Widget          FormatWidget(name,parent)

String  name;
Widget          parent;

{
        return(XtCreateManagedWidget(name,formWidgetClass,parent,NULL,ZERO));
}

void    FillMenu(parent,number,items,widgets,callbacks)

int     number;
MenuItem        items[];
```

```
Widget          parent, widgets[];
XtCallbackRec        callbacks[];

{
        Arg     args[4];
        int     i, call_i=0;
        Icon    icon=FindIcon("right");

        for(i=0;i<number;i++) {
                int     argc=0;

                XtSetArg(args[argc],XtNlabel,items[i].label); argc++;
                if (items[i].widgetClass==smeBSBprObjectClass) {
                        XtSetArg(args[argc],XtNmenuName,items[i].hook); argc++;
                        XtSetArg(args[argc],XtNrightMargin,4+icon->width); argc++;
                        XtSetArg(args[argc],XtNrightBitmap,icon->pixmap); argc++;
                }

widgets[i]=XtCreateManagedWidget(items[i].name,items[i].widgetClass,parent,args,argc)
;
                if (items[i].widgetClass==smeBSBObjectClass) { /* Add Callbacks */
                        XtAddCallbacks(widgets[i],XtNcallback,&callbacks[call_i]);
                        while(callbacks[call_i].callback!=NULL) call_i++;
                        call_i++;
                }
        }
}

void    SimpleMenu(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;
```

```
{
        int     *hook=(int *)closure, no_child, child, argc=0;
        Widget          menu=XtParent(w), button;
        WidgetList      children;
        char    *label;
        Arg     args[3];

        XtSetArg(args[argc],XtNlabel,&label); argc++;
        XtGetValues(w,args,argc); argc=0;
        XtSetArg(args[argc],XtNchildren,&children); argc++;
        XtSetArg(args[argc],XtNnumChildren,&no_child); argc++;
        XtSetArg(args[argc],XtNbutton,&button); argc++;
        XtGetValues(menu,args,argc); argc=0;
        for(child=0;children[child]!=w && child<no_child;) child++;
        if (w!=children[child]) Eprintf("SimpleMenu: menu error\n");
        *hook=child;
        XtSetArg(args[argc],XtNlabel,label); argc++;
        XtSetValues(button,args,argc);
}

void    NumIncDec(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;

{
        NumInput        data=(NumInput)closure;
        Arg     args[1];
        char    text[STRLEN];

        *data->value+=(w==data->widgets[0])?-1:1;
        sprintf(text,data->format,*data->value);
```

```
        if (data->min==*data->value) XtSetSensitive(data->widgets[0],False);
        else XtSetSensitive(data->widgets[0],True);
        if (data->max==*data->value) XtSetSensitive(data->widgets[1],False);
        else XtSetSensitive(data->widgets[1],True);
        XtSetArg(args[0],XtNlabel,text);
        XtSetValues(data->widgets[2],args,ONE);
}

void    FloatIncDec(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        FloatInput      data=(FloatInput)closure;
        Arg     args[1];
        char    text[STRLEN];
        float   percent=*(float *)call_data;

        *data->value=data->min+(double)percent*(data->max-data->min);
        sprintf(text,data->format,*data->value);
        XtSetArg(args[0],XtNlabel,text);
        XtSetValues(data->widgets[0],args,ONE);
}

/*      Function Name:      ChangeYN
 *      Description:  Toggle YN widget state
 *      Arguments:    w - toggling widget
 *                          closure - pointer to boolean state
 *                          call_data - not used
 *      Returns:      none.
 */
```

```
void    ChangeYN(w,closure,call_data)

Widget        w;
caddr_t       closure, call_data;

{
        Boolean        *bool=(Boolean *)closure;
        Icon    icon=FindIcon((*bool != True)?"confirm":"cancel");
        Arg     args[4];
        int     argc=0;

        *bool = ! *bool;
        XtSetArg(args[argc],XtNbitmap,icon->pixmap); argc++;
        XtSetArg(args[argc],XtNheight,icon->height+2); argc++;
        XtSetArg(args[argc],XtNwidth,icon->width+2); argc++;
        XtSetValues(w,args,argc);
}

int     TextWidth(max,text,font)

int     max;
String  text;
XFontStruct   *font;

{
        int     i=0, j;

        while(text[i]!='\0') {
                int     width;

                for(j=0;text[i+j]!='\0' && text[i+j]!='\n';) j++;
                width=XTextWidth(font,&text[i],j);
```

```
/*
 * Image.c - Image widget
 *
 */

#define XtStrlen(s)          ((s) ? strlen(s) : 0)

#include <stdio.h>
#include <ctype.h>
#include <X11/IntrinsicP.h>
#include <X11/StringDefs.h>
#include <X11/Xaw/XawInit.h>
#include "../include/ImageP.h"

#define streq(a,b) (strcmp( (a), (b) ) == 0)


/****************************************************************
 *
 * Full class record constant
 *
 ****************************************************************/

/* Private Data */

static  char   defaultTranslations[]=
        "<Btn1Down>: notify()\n\
         <Btn1Motion>: notify()\n\
         <Btn1Up>: notify()";
#define offset(field) XtOffset(ImageWidget, field)
static XtResource resources[] = {
        {XtNbitmap, XtCPixmap, XtRBitmap, sizeof(Pixmap),
```

```
        offset(image.pixmap), XtRImmediate, (caddr_t)None},
        {XtNcallback, XtCCallback, XtRCallback, sizeof(XtPointer),
        offset(image.callbacks), XtRCallback, (XtPointer)NULL},
};

static void Initialize();
static void Resize();
static void Redisplay();
static Boolean SetValues();
static void ClassInitialize();
static void Destroy();
static XtGeometryResult QueryGeometry();

static  void   Notify(), GetBitmapInfo();

static  XtActionsRec        actionsList[]={
        {"notify",     Notify},
};

ImageClassRec imageClassRec = {
  {
/* core_class fields */
#define superclass              (&simpleClassRec)
   /* superclass                */      (WidgetClass) superclass,
   /* class_name                */      "Image",
   /* widget_size               */      sizeof(ImageRec),
   /* class_initialize          */      ClassInitialize,
   /* class_part_initialize     */      NULL,
   /* class_inited              */      FALSE,
   /* initialize                */      Initialize,
   /* initialize_hook           */      NULL,
   /* realize                   */      XtInheritRealize,
```

```
    /* actions                  */  actionsList,
    /* num_actions              */  XtNumber(actionsList),
    /* resources                */  resources,
    /* num_resources            */  XtNumber(resources),
    /* xrm_class                */  NULLQUARK,
    /* compress_motion          */  TRUE,
    /* compress_exposure        */  TRUE,
    /* compress_enterleave      */  TRUE,
    /* visible_interest         */  FALSE,
    /* destroy                  */  Destroy,
    /* resize                   */  Resize,
    /* expose                   */  Redisplay,
    /* set_values               */  SetValues,
    /* set_values_hook          */  NULL,
    /* set_values_almost        */  XtInheritSetValuesAlmost,
    /* get_values_hook          */  NULL,
    /* accept_focus             */  NULL,
    /* version                  */  XtVersion,
    /* callback_private         */  NULL,
    /* tm_table                 */  defaultTranslations,
    /* query_geometry           */  QueryGeometry,
    /* display_accelerator      */  XtInheritDisplayAccelerator,
    /* extension                */  NULL
  },
/* Simple class fields initialization */
  {
    /* change_sensitive         */  XtInheritChangeSensitive
  }
};
WidgetClass imageWidgetClass = (WidgetClass)&imageClassRec;
/*******************************************************************
 *
```

```
 * Private Procedures
 *
 ********************************************************************/

static void ClassInitialize()
{
        extern void XmuCvtStringToBitmap();
    static XtConvertArgRec screenConvertArg[] = {
      {XtWidgetBaseOffset, (caddr_t) XtOffset(Widget, core.screen),
           sizeof(Screen *)}
    };
    XawInitializeWidgetSet();
        XtAddConverter("String", "Bitmap", XmuCvtStringToBitmap,
                screenConvertArg, XtNumber(screenConvertArg));
} /* ClassInitialize */

/* ARGSUSED */
static void Initialize(request,new)

Widget request, new;

{
    ImageWidget iw = (ImageWidget) new;

        Dprintf("ImageInitialize\n");
        if (iw->image.pixmap==NULL)
                XtErrorMsg("NoBitmap","asciiSourceCreate","XawError",
                "Image widget has no bitmap.",NULL,0);
        GetBitmapInfo(new);
        if (iw->image.map_width<=0 || iw->image.map_height<=0)
                XtErrorMsg("NoDimension","asciiSourceCreate","XawError",
                "Image widget illegal map dimension.",NULL,0);
```

```
    if (iw->core.width == 0) iw->core.width=iw->image.map_width;
        if (iw->core.height == 0) iw->core.height=iw->image.map_height;

    (*XtClass(new)->core_class.resize) ((Widget)iw);

} /* Initialize */

/*
 * Repaint the widget window
 */

/* ARGSUSED */
static void Redisplay(w, event, region)
    Widget w;
    XEvent *event;
    Region region;
{
   ImageWidget iw = (ImageWidget) w;

        Dprintf("ImageRedisplay\n");
        if (region != NULL &&
        XRectInRegion(region, 0, 0,
                    iw->image.map_width, iw->image.map_height)
            == RectangleOut)
      return;

        XCopyArea(
                XtDisplay(w), iw->image.pixmap, XtWindow(w),
DefaultGC(XtDisplay(w),XDefaultScreen(XtDisplay(w))),
                0, 0, iw->image.map_width, iw->image.map_height, 0, 0);
}
```

```
static void Resize(w)
    Widget w;
{
    ImageWidget iw = (ImageWidget)w;
        Dprintf("ImageResize\n");
}

/*
 * Set specified arguments into widget
 */

static Boolean SetValues(current, request, new, args, num_args)
    Widget current, request, new;
    ArgList args;
    Cardinal *num_args;
{
    ImageWidget curiw = (ImageWidget) current;
    ImageWidget reqiw = (ImageWidget) request;
    ImageWidget newiw = (ImageWidget) new;
    Boolean    redisplay = False;

    /* recalculate the window size if something has changed. */

        if (curiw->image.pixmap != newiw->image.pixmap)
XFreePixmap(XtDisplay(curiw),curiw->image.pixmap);
        GetBitmapInfo(newiw);
        newiw->core.width=newiw->image.map_width;
        newiw->core.height=newiw->image.map_height;
        redisplay=True;

    return redisplay || XtIsSensitive(current) != XtIsSensitive(new);
}
```

```
static void Destroy(w)
    Widget w;
{
    ImageWidget lw = (ImageWidget)w;

        Dprintf("ImageDestroy\n");
}


static XtGeometryResult QueryGeometry(w, intended, preferred)
    Widget w;
    XtWidgetGeometry *intended, *preferred;
{
    register ImageWidget iw = (ImageWidget)w;

    preferred->request_mode = CWWidth | CWHeight;
    preferred->width = iw->image.map_width;
    preferred->height = iw->image.map_height;
    if (  ((intended->request_mode & (CWWidth | CWHeight))
                == (CWWidth | CWHeight)) &&
          intended->width == preferred->width &&
          intended->height == preferred->height)
        return XtGeometryYes;
    else if (preferred->width == w->core.width &&
            preferred->height == w->core.height)
        return XtGeometryNo;
    else
        return XtGeometryAlmost;
}

static  void   GetBitmapInfo(w)
```

```
Widget      w;

{
        ImageWidget  iw=(ImageWidget)w;
        unsigned int  depth, bw;
        Window       root;
        int     x, y;
        unsigned int  width, height;
        char    buf[BUFSIZ];

        if (iw->image.pixmap != None) {
                if
(!XGetGeometry(XtDisplayOfObject(w),iw->image.pixmap,&root,&x,&y,&width,&heig
ht,&bw,&depth)) {
                        sprintf(buf, "ImageWidget: %s %s \"%s\".", "Could not",
                        "get Bitmap geometry information for Image  ",
                        XtName(w));
                        XtAppError(XtWidgetToApplicationContext(w), buf);
                }
                iw->image.map_width=(Dimension)width;
                iw->image.map_height=(Dimension)height;
        }
}

/*
 *      Action Procedures
 */

static  void   Notify(w,event,params,num_params)

Widget      w;
XEvent      *event;
```

```
String *params;
Cardinal        *mum_params;

{
        ImageWidget iw=(ImageWidget)w;
        XButtonEvent        *buttonevent=&event->xbutton;
        int     posn[2]={buttonevent->x,buttonevent->y};

        if (iw->image.map_width<=posn[0] || posn[0]<0 ||
                iw->image.map_height<=posn[1] || posn[1]<0) Dprintf("No
ImageNotify\n");
        else {
                Dprintf("ImageNotify\n");
                XtCallCallbackList(w,iw->image.callbacks,posn);
        }
}
```

source/ImpKlicsTestSA.c

```
/*
	Test harness for KlicsFrameSA() in Klics.SA
*/

#include	"xwave.h"
#include	"KlicsSA.h"

void	ImpKlicsTestSA(w,closure,call_data)

Widget		w;
caddr_t		closure, call_data;

{
	int	sizeY=SA_WIDTH*SA_HEIGHT,
			sizeUV=SA_WIDTH*SA_HEIGHT/4;
	short	*dst[3]={
		(short *)MALLOC(sizeof(short)*sizeY),
		(short *)MALLOC(sizeof(short)*sizeUV),
		(short *)MALLOC(sizeof(short)*sizeUV),
	}, *src[3];
	Video	video=(Video)MALLOC(sizeof(VideoRec));
	int	i, z;
	char	file_name[STRLEN];
	Bits	bfp;
	Boolean		stillvid;

	strcpy(video->name,((XawListReturnStruct *)call_data)->string);
```

```
sprintf(file_name,"%s%s/%s%s\0",global->home,KLICS_SA_DIR,video->name,KLICS
_SA_EXT);
	bfp=bopen(file_name,"r");
	bread(&stillvid,1,bfp);
	bread(&video->size[2],sizeof(int)*8,bfp);
	video->data[0]=(short **)MALLOC(sizeof(short *)*video->size[2]);
	video->data[1]=(short **)MALLOC(sizeof(short *)*video->size[2]);
	video->data[2]=(short **)MALLOC(sizeof(short *)*video->size[2]);
	video->disk=False;
	video->type=YUV;
	video->size[0]=SA_WIDTH;
	video->size[1]=SA_HEIGHT;
	video->UVsample[0]=1;
	video->UVsample[1]=1;
	video->trans.type=TRANS_None;
	for(z=0;z<video->size[2];z++) {
		NewFrame(video,z);
		src[0]=video->data[0][z];
		src[1]=video->data[1][z];
		src[2]=video->data[2][z];
		KlicsFrameSA(z==0 || stillvid?STILL:SEND,src,dst,bfp);
		SaveFrame(video,z);
		FreeFrame(video,z);
	}
	bclose(bfp);
	video->next=global->videos;
	global->videos=video;
	XtFree(dst[0]);
	XtFree(dst[1]);
	XtFree(dst[2]);
}
```

source/ImportKlics.c

```
/*
 *      Importing raw Klics binary files
 */

#include        "xwave.h"
#include        "Klics.h"

extern Bits     bopen();
extern void     bclose(), bread(), bwrite(), bflush();

extern void     SkipFrame();
extern int      HuffRead();
extern Boolean          BlockZero();
extern void     ZeroCoeffs();
extern int      ReadInt();
extern int      Decide();
extern double           DecideDouble();

Boolean         BoolToken(bfp)

Bits    bfp;

{
        Boolean         token;

        bread(&token,1,bfp);
        return(token);
}
```

```
void    HuffBlock(block,bfp)

Block  block;
Bits    bfp;

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
                block[X][Y]=HuffRead(bfp);
}

void    PrevBlock(old,addr,x,y,z,oct,sub,channel,ctrl)

Block   old, addr;
int     x, y, z, oct, sub, channel;
CompCtrl      ctrl;

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++) {

addr[X][Y]=Access((x<<1)+X,(y<<1)+Y,oct,sub,Size(ctrl->dst,channel,0));
                old[X][Y]=ctrl->dst->data[channel][z][addr[X][Y]];
        }
}

void    DeltaBlock(new,old,delta,step)

Block  new, old, delta;
int     step;
```

```
{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)

new[X][Y]=old[X][Y]+delta[X][Y]*step+(delta[X][Y]!=0?negif(delta[X][Y]<0,(step-1)
>>1):0);
}

void    UpdateBlock(new,addr,z,channel,ctrl)

int     z, channel;
Block   new, addr;
CompCtrl        ctrl;

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
                ctrl->dst->data[channel][z][addr[X][Y]]=(short)new[X][Y];
}

void    ReadKlicsHeader(ctrl)

CompCtrl        ctrl;

{
        KlicsHeaderRec          head;
        int     i;
        Video   dst=ctrl->dst;

        fread(&head,sizeof(KlicsHeaderRec),1,ctrl->bfp->fp);
```

```
        ctrl->stillvid=head.stillvid;
        ctrl->auto_q=head.auto_q;
        ctrl->buf_switch=head.buf_switch;
        ctrl->quant_const=head.quant_const;
        ctrl->thresh_const=head.thresh_const;
        ctrl->cmp_const=head.cmp_const;
        ctrl->fps=head.fps;
        for(i=0;i<5;i++) ctrl->base_factors[i]=head.base_factors[i];
        ctrl->diag_factor=head.diag_factor;
        ctrl->chrome_factor=head.chrome_factor;
        ctrl->decide=head.decide;
        strcpy(dst->name,ctrl->bin_name);
        dst->type=head.type;
        dst->disk=head.disk;
        dst->gamma=head.gamma;
        dst->rate=head.rate;
        dst->start=head.start;
        for(i=0;i<3;i++) dst->size[i]=head.size[i];
        for(i=0;i<2;i++) dst->UVsample[i]=head.UVsample[i];
        dst->trans=head.trans;
        dst->precision=head.precision;
        for(i=0;i<(dst->type==MONO?1:3);i++)
                dst->data[i]=(short **)MALLOC(dst->size[2]*sizeof(short *));
}

void    WriteKlicsHeader(ctrl)

CompCtrl        ctrl;

{
        KlicsHeaderRec          head;
        int     i;
```

```
        head.stillvid=ctrl->stillvid;
        head.auto_q=ctrl->auto_q;
        head.buf_switch=ctrl->buf_switch;
        head.quant_const=ctrl->quant_const;
        head.thresh_const=ctrl->thresh_const;
        head.cmp_const=ctrl->cmp_const;
        head.fps=ctrl->fps;
        for(i=0;i<5;i++) head.base_factors[i]=ctrl->base_factors[i];
        head.diag_factor=ctrl->diag_factor;
        head.chrome_factor=ctrl->chrome_factor;
        head.decide=ctrl->decide;
        head.type=ctrl->dst->type;
        head.disk=ctrl->dst->disk;
        head.gamma=ctrl->dst->gamma;
        head.rate=ctrl->dst->rate;
        head.start=ctrl->dst->start;
        for(i=0;i<3;i++) head.size[i]=ctrl->dst->size[i];
        for(i=0;i<2;i++) head.UVsample[i]=ctrl->dst->UVsample[i];
        head.trans=ctrl->dst->trans;
        head.precision=ctrl->dst->precision;
        fwrite(&head,sizeof(KlicsHeaderRec),1,ctrl->bfp->fp);
}

void    KlicsTree(mode,x,y,z,oct,sub,channel,ctrl)

int     mode, x, y, z, oct, sub, channel;
CompCtrl    ctrl;

{
        Block   addr, old, new, delta, zero_block={{0,0},{0,0}};
        double          norms[3]={ctrl->quant_const,ctrl->thresh_const,ctrl->cmp_const};
        int     step;
```

```
PrevBlock(old,addr,x,y,z,oct,sub,channel,ctrl);
if (mode!=VOID) {
        CalcNormals(ctrl,oct,sub,channel,norms);
        step=norms[0]<1.0?1:(int)norms[0];
        if (mode==STILL || BlockZero(old)) {
                if (BoolToken(ctrl->bfp)) { /* NON_ZERO_STILL */
                        Dprintf("NON_ZERO_STILL\n");
                        HuffBlock(delta,ctrl->bfp);
                        DeltaBlock(new,old,delta,step);
                        UpdateBlock(new,addr,z,channel,ctrl);
                } else {
                        Dprintf("ZERO_STILL\n");
                        mode=STOP;                      /* ZERO_STILL */
                }
        } else {
                if (!BoolToken(ctrl->bfp)) {          /* BLOCK_SAME */
                        Dprintf("BLOCK_SAME\n");
                        mode=STOP;
                } else {
                        if (!BoolToken(ctrl->bfp)) {          /* ZERO_VID */
                                Dprintf("ZERO_VID\n");
                                ZeroCoeffs(ctrl->dst->data[channel][z],addr);
                                mode=VOID;
                        } else {                                        /*
BLOCK_CHANGE */
                                Dprintf("BLOCK_CHANGE\n");
                                HuffBlock(delta,ctrl->bfp);
                                DeltaBlock(new,old,delta,step);
                                UpdateBlock(new,addr,z,channel,ctrl);
                        }
                }
        }
```

```
	} else {
		if (BlockZero(old)) mode=STOP;
		else {
			ZeroCoeffs(ctrl->dst->data[channel][z],addr);
			mode=VOID;
		}
	}
	if (oct>0 && mode!=STOP) {
		Boolean	decend=mode==VOID?True:BoolToken(ctrl->bfp);
		int	X, Y;

		Dprintf("x=%d, y=%d, oct=%d sub=%d mode
%d\n",x,y,oct,sub,mode);
		if (decend) {
			if (mode!=VOID) Dprintf("OCT_NON_ZERO\n");
			for(Y=0;Y<2;Y++) for(X=0;X<2;X++)
				KlicsTree(mode,x*2+X,y*2+Y,z,oct-1,sub,channel,ctrl);
		} else if (mode!=VOID) Dprintf("OCT_ZERO\n");
	}
}

void	KlicsLPF(mode,z,ctrl)

CompCtrl	ctrl;
int	mode, z;

{
	Block	addr, old, new, delta;
	int	channel, channels=ctrl->dst->type==MONO?1:3, x, y,
			octs_lum=ctrl->dst->trans.wavelet.space[0],

size[2]={Size(ctrl->dst,0,0)>>octs_lum+1,Size(ctrl->dst,0,1)>>octs_lum+1};
```

```
	for(y=0;y<size[1];y++) for(x=0;x<size[0];x++) {
		Boolean		lpf_loc=True;

		if (mode!=STILL) {
			lpf_loc=BoolToken(ctrl->bfp); /*
LPF_LOC_ZERO/LPF_LOC_NON_ZERO */

Dprintf("%s\n",lpf_loc?"LPF_LOC_NON_ZERO":"LPF_LOC_ZERO");
		}
		if (lpf_loc) for(channel=0;channel<channels;channel++) {
			int
octs=ctrl->dst->trans.wavelet.space[ctrl->dst->type==YUV && channel!=0?1:0],
					X, Y, step, value, bits=0;
			double
norms[3]={ctrl->quant_const,ctrl->thresh_const,ctrl->cmp_const};

			PrevBlock(old,addr,x,y,z,octs-1,0,channel,ctrl);
			CalcNormals(ctrl,octs-1,0,channel,norms);
			step=norms[0]<1.0?1:(int)norms[0];
			if (mode==STILL) {
				for(bits=0,
value=((1<<8+ctrl->dst->precision)-1)/step;value!=0;bits++)
					value=value>>1;
				for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
					delta[X][Y]=ReadInt(bits,ctrl->bfp);
				DeltaBlock(new,old,delta,step);
				UpdateBlock(new,addr,z,channel,ctrl);
			} else {
				if (BoolToken(ctrl->bfp)) { /*
LPF_ZERO/LPF_NON_ZERO */
					Dprintf("LPF_NON_ZERO\n");
					HuffBlock(delta,ctrl->bfp);
```

```
                                DeltaBlock(new,old,delta,step);
                                UpdateBlock(new,addr,z,channel,ctrl);
                        } else Dprintf("LPF_ZERO\n");
                }
            }
        }
}

void    KlicsFrame(ctrl,z)

CompCtrl    ctrl;
int     z;

{
        Video   dst=ctrl->dst;
        int     sub, channel, x, y, mode=ctrl->stillvid || z==0?STILL:SEND,
                        octs_lum=dst->trans.wavelet.space[0],

size[2]={Size(dst,0,0)>>1+octs_lum,Size(dst,0,1)>>1+octs_lum};

        NewFrame(dst,z);
        CopyFrame(dst,z-1,z,ctrl->stillvid || z==0);
        if (z!=0 && ctrl->auto_q) {

ctrl->quant_const+=(double)(HISTO/2+ReadInt(HISTO_BITS,ctrl->bfp))*HISTO_DE
LTA*2.0/HISTO-HISTO_DELTA;
                ctrl->quant_const=ctrl->quant_const<0.0?0.0:ctrl->quant_const;
                Dprintf("New quant %f\n",ctrl->quant_const);
        }
        KlicsLPF(mode,z,ctrl);
        for(y=0;y<size[1];y++) for(x=0;x<size[0];x++) {
                if (BoolToken(ctrl->bfp)) {
```

```
                    Dprintf("LOCAL_NON_ZERO\n");
                    for(channel=0;channel<(dst->type==MONO?1:3);channel++) {
                        int     octs=dst->trans.wavelet.space[dst->type==YUV
&& channel!=0?1:0];

                        if (BoolToken(ctrl->bfp)) {
                            Dprintf("CHANNEL_NON_ZERO\n");
                            for(sub=1;sub<4;sub++)
                                KlicsTree(mode,x,y,z,octs-1,sub,channel,ctrl);
                        } else Dprintf("CHANNEL_ZERO\n");
                    }
                } else Dprintf("LOCAL_ZERO\n");
        }
}

void    ImportKlics(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        char    file_name[STRLEN];
        CompCtrlRec ctrl;
        int     i, z;

        ctrl.dst=(Video)MALLOC(sizeof(VideoRec));
        strcpy(ctrl.bin_name,((XawListReturnStruct *)call_data)->string);

sprintf(file_name,"%s%s/%s%s\0",global->home,KLICS_DIR,ctrl.bin_name,KLICS_EX
T);
        ctrl.bfp=bopen(file_name,"r");
        ReadKlicsHeader(&ctrl);
```

```
        if (ctrl.dst->disk) SaveHeader(ctrl.dst);
        for(z=0;z<ctrl.dst->size[2];z++) {
                if (z==0 || !ctrl.buf_switch) KlicsFrame(&ctrl,z);
                else {
                        if (BoolToken(ctrl.bfp)) KlicsFrame(&ctrl,z);
                        else SkipFrame(ctrl.dst,z);
                }
                if (z>0) {
                        SaveFrame(ctrl.dst,z-1);
                        FreeFrame(ctrl.dst,z-1);
                }
        }
        SaveFrame(ctrl.dst,ctrl.dst->size[2]-1);
        FreeFrame(ctrl.dst,ctrl.dst->size[2]-1);
        bclose(ctrl.bfp);
        ctrl.dst->next=global->videos;
        global->videos=ctrl.dst;
}
```

```
source/ImportKlicsSA.c

****************************/

/*
 *      Importing raw Klics binary files
 *
 *      Stand Alone version
 */

#include        "KlicsSA.h"

extern void     Convolve();

/* useful X definitions */
typedef char    Boolean;
#define True    1
#define False   0
#define String  char*

extern int      HuffReadSA();
extern Boolean          BlockZeroSA();
extern void     ZeroCoeffsSA();
extern int      ReadIntSA();
extern int      DecideSA();
extern double           DecideDoubleSA();

Boolean         BoolTokenSA(bfp)

Bits    bfp;

{
```

```
        Boolean         token;

        bread(&token,1,bfp);
        return(token);
}

void    HuffBlockSA(block,bfp)

Block   block;
Bits    bfp;

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
                block[X][Y]=HuffReadSA(bfp);
}

void    PrevBlockSA(old,addr,x,y,oct,sub,channel,dst)

Block   old, addr;
int     x, y, oct, sub, channel;
short   *dst[3];

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++) {
                addr[X][Y]=AccessSA((x<<1)+X,(y<<1)+Y,oct,sub,channel);
                old[X][Y]=dst[channel][addr[X][Y]];
        }
}
```

```
void    DeltaBlockSA(new,old,delta,step)

Block  new, old, delta;
int     step;

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)

new[X][Y]=old[X][Y]+delta[X][Y]*step+(delta[X][Y]!=0?negif(delta[X][Y]<0,(step-1)
>>1):0);
}

void    UpdateBlockSA(new,addr,channel,dst)

int     channel;
Block  new, addr;
short  *dst[3];

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
                dst[channel][addr[X][Y]]=(short)new[X][Y];
}

void    KlicsTreeSA(mode,x,y,oct,sub,channel,dst,bfp,quant_const)

int     mode, x, y, oct, sub, channel;
short  *dst[3];
Bits    bfp;
```

```
double          quant_const;

{
        Block   addr, old, new, delta, zero_block={{0,0},{0,0}};
        double          norms[3]={quant_const,thresh_const,cmp_const};
        int     step;

        PrevBlockSA(old,addr,x,y,oct,sub,channel,dst);
        if (mode!=VOID) {
                CalcNormalsSA(oct,sub,channel,norms,quant_const);
                step=norms[0]<1.0?1:(int)norms[0];
                if (mode==STILL || BlockZero(old)) {
                        if (BoolTokenSA(bfp)) { /* NON_ZERO_STILL */
                                Dprintf("NON_ZERO_STILL\n");
                                HuffBlockSA(delta,bfp);
                                DeltaBlockSA(new,old,delta,step);
                                UpdateBlockSA(new,addr,channel,dst);
                        } else {
                                Dprintf("ZERO_STILL\n");
                                mode=STOP;                      /* ZERO_STILL */
                        }
                } else {
                        if (!BoolTokenSA(bfp)) {     /* BLOCK_SAME */
                                Dprintf("BLOCK_SAME\n");
                                mode=STOP;
                        } else {
                                if (!BoolTokenSA(bfp)) {     /* ZERO_VID */
                                        Dprintf("ZERO_VID\n");
                                        ZeroCoeffsSA(dst[channel],addr);
                                        mode=VOID;
                                } else {                                /*
BLOCK_CHANGE */
```

```
                                        Dprintf("BLOCK_CHANGE\n");
                                        HuffBlockSA(delta,bfp);
                                        DeltaBlockSA(new,old,delta,step);
                                        UpdateBlockSA(new,addr,channel,dst);
                                }
                        }
                }
        } else {
                if (BlockZeroSA(old)) mode=STOP;
                else {
                        ZeroCoeffsSA(dst[channel],addr);
                        mode=VOID;
                }
        }
        if (oct>0 && mode!=STOP) {
                Boolean         decend=mode==VOID?True:BoolTokenSA(bfp);
                int     X, Y;

                Dprintf("x=%d, y=%d, oct=%d sub=%d mode
%d\n",x,y,oct,sub,mode);
                if (decend) {
                        if (mode!=VOID) Dprintf("OCT_NON_ZERO\n");
                        for(Y=0;Y<2;Y++) for(X=0;X<2;X++)

KlicsTreeSA(mode,x*2+X,y*2+Y,oct-1,sub,channel,dst,bfp,quant_const);
                } else if (mode!=VOID) Dprintf("OCT_ZERO\n");
        }
}

void    KlicsLPF_SA(mode,dst,bfp,quant_const)

int     mode;
```

```
short   *dst[3];
Bits    bfp;
double          quant_const;

{
        Block  addr, old, new, delta;
        int    channel, channels=3, x, y,
                       octs_lum=3,

size[2]={SA_WIDTH>>octs_lum+1,SA_HEIGHT>>octs_lum+1};

        for(y=0;y<size[1];y++) for(x=0;x<size[0];x++) {
                Boolean         lpf_loc=True;

                if (mode!=STILL) {
                        lpf_loc=BoolTokenSA(bfp); /*
LPF_LOC_ZERO/LPF_LOC_NON_ZERO */

Dprintf("%s\n",lpf_loc?"LPF_LOC_NON_ZERO":"LPF_LOC_ZERO");
                }
                if (lpf_loc) for(channel=0;channel<channels;channel++) {
                        int     octs=channel!=0?2:3,
                                        X, Y, step, value, bits=0;
                        double          norms[3]={quant_const,thresh_const,cmp_const};

                        PrevBlockSA(old,addr,x,y,octs-1,0,channel,dst);
                        CalcNormalsSA(octs-1,0,channel,norms,quant_const);
                        step=norms[0]<1.0?1:(int)norms[0];
                        if (mode==STILL) {
                                for(bits=0,
value=((1<<8+SA_PRECISION)-1)/step;value!=0;bits++)
                                        value=value>>1;
```

```
                    for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
                        delta[X][Y]=ReadIntSA(bits,bfp);
                    DeltaBlockSA(new,old,delta,step);
                    UpdateBlockSA(new,addr,channel,dst);
                } else {
                    if (BoolTokenSA(bfp)) { /* LPF_ZERO/LPF_NON_ZERO
*/

                        Dprintf("LPF_NON_ZERO\n");
                        HuffBlockSA(delta,bfp);
                        DeltaBlockSA(new,old,delta,step);
                        UpdateBlockSA(new,addr,channel,dst);
                    } else Dprintf("LPF_ZERO\n");
                }
            }
        }
}

void    KlicsFrameSA(mode,src,dst,bfp)

int     mode;
short   *src[3], *dst[3];
Bits    bfp;

{
        int     sub, channel, x, y, i,
                        octs_lum=3,

size[2]={SA_WIDTH>>1+octs_lum,SA_HEIGHT>>1+octs_lum};
        double          quant_const;

        bread((char *)&quant_const,sizeof(double)*8,bfp);
        KlicsLPF_SA(mode,dst,bfp,quant_const);
```

```
	for(y=0;y<size[1];y++) for(x=0;x<size[0];x++) {
		if (BoolTokenSA(bfp)) {
			Dprintf("LOCAL_NON_ZERO\n");
			for(channel=0;channel<3;channel++) {
				int	octs=channel!=0?2:3;

				if (BoolTokenSA(bfp)) {
					Dprintf("CHANNEL_NON_ZERO\n");
					for(sub=1;sub<4;sub++)

KlicsTreeSA(mode,x,y,octs-1,sub,channel,dst,bfp,quant_const);
				} else Dprintf("CHANNEL_ZERO\n");
			}
		} else Dprintf("LOCAL_ZERO\n");
	}
	for(channel=0;channel<3;channel++) {
		int
frame_size[2]={SA_WIDTH>>(channel==0?0:1),SA_HEIGHT>>(channel==0?0:1
)},
				frame_area=frame_size[0]*frame_size[1];

		for(i=0;i<frame_area;i++) src[channel][i]=dst[channel][i];
		Convolve(src[channel],False,frame_size,channel==0?3:2,0);
		for(i=0;i<frame_area;i++)
src[channel][i]=src[channel][i]>>SA_PRECISION;
	}
}
```

source/InitFrame.c

```
/*
        Initialise frame structure for Frame command widget
*/

#include        "../include/xwave.h"
#define         FRAME_ICONS     14
#define         TRANS_MENU      1
#define         COMP_MENU       2

extern void     CopyVideo();
extern void     Compare();
extern void     NA();
extern void     FrameDestroy();
extern void     Examine();
extern void     FramePointYN();
extern void     FrameInfo();
extern void     FrameMerge();
extern void     Movie();
extern void     PostScript();
extern void     Select();
extern void     Spectrum();
extern void     NewPoint();
extern void     Transform();
extern void     Compress();
extern String   *VideoCurrentList();
extern void     KlicsSA();

void    InitFrame       (w,closure,call_data)
```

```
Widget      w;
caddr_t     closure, call_data;

{
        XawListReturnStruct *name=(XawListReturnStruct *)call_data;
        Video  video=FindVideo(name->string,global->videos);
        Frame  frame=(Frame)MALLOC(sizeof(FrameRec));
        Widget      shell[2], form, widgets[FRAME_ICONS],
trans_widgets[TRANS_MENU], comp_widgets[COMP_MENU];
        Arg    args[7];
        Pixmap      pixmap;
        int    view[2]={15+video->size[0],15+video->size[1]};
        FormItem    items[]={
                {"frm_cancel",      "frame_close",          0,0,FW_icon,NULL},
                {"frm_copy", "copy",                        1,0,FW_icon,NULL},
                {"frm_exam",        "examine",              2,0,FW_icon,NULL},
                {"frm_point_yn","point_y",            3,0,FW_icon,NULL},
                {"frm_transform","transform",
4,0,FW_icon_button,"frm_trans_menu"},
                {"frm_info_yn",     "info",
5,0,FW_icon,NULL},
                {"frm_merge",       "merge",                6,0,FW_toggle,NULL},
                {"frm_compress","code",
7,0,FW_icon_button,"frm_comp_menu"},
                {"frm_movie",       "movie",                8,0,FW_icon,NULL},
                {"frm_postscript","postscript",       9,0,FW_icon,NULL},
                {"frm_compare",     "compare",              10,0,FW_icon,NULL},
                {"frm_view", NULL,
0,1,FW_view,(String)view},
                {"frm_label", video->name,            0,12,FW_label,NULL},
                {"frm_colors",      "colors",               13,12,FW_icon,NULL},
        };
```

```
Selection   sel=(Selection)MALLOC(sizeof(SelectItem));
MenuItem    trans_menu[TRANS_MENU]={
    {"trans_Wavelet",smeBSBObjectClass,"Wavelet",NULL},
};
MenuItem    comp_menu[COMP_MENU]={
    {"comp_KLICS",smeBSBObjectClass,"KLICS",NULL},
    {"comp_KLICS_SA",smeBSBObjectClass,"KLICS SA",NULL},
};
XtCallbackRec       frame_call[]={
    {FrameDestroy,(caddr_t)frame}, {Free,(caddr_t)sel}, {NULL,NULL},
    {CopyVideo,(caddr_t)video}, {NULL,NULL},
    {Examine,(caddr_t)frame}, {NULL,NULL},
    {FramePointYN,(caddr_t)frame}, {NULL,NULL},
    {FrameInfo,(caddr_t)frame}, {NULL,NULL},
    {FrameMerge,(caddr_t)frame}, {NULL,NULL},
    {Movie,(caddr_t)frame}, {NULL,NULL},
    {PostScript,(caddr_t)frame}, {NULL,NULL},
    {Select,(caddr_t)sel}, {NULL,NULL},
    {Spectrum,(caddr_t)frame}, {NULL,NULL},
}, image_call[]={
    {NewPoint,(caddr_t)frame}, {NULL,NULL},
}, trans_call[]={
    {Transform,(caddr_t)video}, {NULL,NULL},
}, comp_call[]={
    {Compress,(caddr_t)video}, {NULL,NULL},
    {KlicsSA,(caddr_t)video}, {NULL,NULL},
};
Colormap    cmap=ChannelCmap(frame->channel=(video->type==MONO
|| video->trans.type!=TRANS_None)?0:3,video->type,video->gamma);

Dprintf("InitFrame\n");
```

```
sel->name="video_Compare";
sel->button="frm_compare";
sel->list_proc=VideoCurrentList;
sel->action_name="Compare videos";
sel->action_proc=Compare;
sel->action_closure=(caddr_t)video;
frame->video=video;
frame->shell=ShellWidget("frm_shell",global->toplevel,SW_top,cmap,NULL);
form=FormatWidget("frm_form",frame->shell);
frame->image_widget=NULL;

frame->msg=NULL;

frame->zoom=0;
frame->frame=0;

frame->point_switch=False;
frame->point_merge=False;

frame->point=(Point)MALLOC(sizeof(PointRec));
frame->point->location[0]=0;
frame->point->location[1]=0;
frame->point->usage=1;
frame->point->next=global->points;
global->points=frame->point;

frame->palette=0;

frame->next=global->frames;
global->frames=frame;

GetFrame(video,frame->frame);
```

```
        pixmap=UpdateImage(frame);

        FillForm(form,FRAME_ICONS,items,widgets,frame_call);
        shell[0]=ShellWidget("frm_trans_menu",widgets[4],SW_menu,NULL,NULL);
        FillMenu(shell[0],TRANS_MENU,trans_menu,trans_widgets,trans_call);
        shell[1]=ShellWidget("frm_comp_menu",widgets[7],SW_menu,NULL,NULL);
        FillMenu(shell[1],COMP_MENU,comp_menu,comp_widgets,comp_call);

        frame->point_merge_widget=widgets[6];

        XtSetArg(args[0],XtNbitmap,pixmap);
        XtSetArg(args[1],XtNwidth,video->size[0]);
        XtSetArg(args[2],XtNheight,video->size[1]);
        XtSetArg(args[3],XtNcallback,image_call);

frame->image_widget=XtCreateManagedWidget("frm_image",imageWidgetClass,widget
s[11],args,FOUR);
        XtSetSensitive(frame->image_widget,False);
        XtSetSensitive(widgets[13],PseudoColor==global->visinfo->class);
        XtPopup(frame->shell,XtGrabNone);
}

Video   FindVideo(name,video)

String  name;
Video   video;

{
        if (video==NULL) return(NULL);
        else if (!strcmp(name,video->name)) return(video);
                else return(FindVideo(name,video->next));
}
```

source/InitMain.c

```
/*
        Initialise menu structure for Main command widget
*/

#include        "../include/xwave.h"

/* Save externs */

extern void     VideoSave();
extern void     VideoXimSave();
extern void     VideoDTSave();
extern void     VideoMacSave();
extern void     VideoHexSave();

/* List externs */

extern String   *VideoList();
extern String   *VideoDropList();
extern String   *VideoCurrentList();
extern String   *KlicsList();
extern String   *KlicsListSA();

/* Import externs */

extern void     ImportKlics();
extern void     ImpKlicsTestSA();

/* Main externs */
```

```
extern void   Select();
extern void   VideoClean();
extern void   Quit();
extern void   VideoLoad();
extern void   InitFrame();
extern void   VideoDrop();
extern void   PlotGraph();

/*    Function Name:     InitMain
 *    Description:   Create main menu button & sub-menus
 *    Arguments:     none
 *    Returns:       none
 */

#define       MAIN_MENU      7
#define       SAVE_MENU      5
#define       IMPT_MENU      2

InitMain()

{
        Widget        form=FormatWidget("xwave_form",global->toplevel), widgets[1],
                      main_shell, main_widgets[MAIN_MENU],
                      save_shell, save_widgets[SAVE_MENU],
                      impt_shell, impt_widgets[IMPT_MENU];
        FormItem      items[]={
                {"xwaveLogo","main",0,0,FW_icon_button,"xwave_main_sh"},
        };
        MenuItem      main_menu[]={
                {"main_Open",smeBSBObjectClass,"Open a video",NULL},
                {"main_Attach",smeBSBObjectClass,"Attach a frame",NULL},
                {"main_Save",smeBSBprObjectClass,"Save a video","xwave_save_sh"},
```

```
		{"main_Drop",smeBSBObjectClass,"Drop a video",NULL},
		{"main_Clean",smeBSBObjectClass,"Clean out videos",NULL},
		{"main_Import",smeBSBprObjectClass,"Import a
video","xwave_impt_sh"},
		{"main_Quit",smeBSBObjectClass,"Quit",NULL},
	}, save_menu[]={
		{"save_menu_vid",smeBSBObjectClass,"Save xwave video",NULL},
		{"save_menu_xim",smeBSBObjectClass,"Save xim video",NULL},
		{"save_menu_dt",smeBSBObjectClass,"Save DT image",NULL},
		{"save_menu_mac",smeBSBObjectClass,"Save mac video",NULL},
		{"save_menu_hex",smeBSBObjectClass,"Save hex dump",NULL},
	}, impt_menu[]={
		{"impt_menu_klics",smeBSBObjectClass,"KLICS",NULL},
		{"impt_menu_klicsSA",smeBSBObjectClass,"KLICS SA",NULL},
	};
	static	SelectItem	selection[]={
		{"video_Open","xwaveLogo",VideoList,"Open a
video",VideoLoad,NULL},
		{"frame_Attach","xwaveLogo",VideoCurrentList,"Attach a
frame",InitFrame,NULL},
		{"video_Drop","xwaveLogo",VideoDropList,"Drop a
video",VideoDrop,NULL},
	}, save_sel[]={
		{"save_vid","xwaveLogo",VideoCurrentList,"Save xwave
video",VideoSave,NULL},
		{"save_xim","xwaveLogo",VideoCurrentList,"Save xim
video",VideoXimSave,NULL},
		{"save_dt","xwaveLogo",VideoCurrentList,"Save DT
image",VideoDTSave,NULL},
		{"save_mac","xwaveLogo",VideoCurrentList,"Save mac
video",VideoMacSave,NULL},
		{"save_hex","xwaveLogo",VideoCurrentList,"Save hex
```

```
'dump",VideoHexSave,NULL},
        }, impt_sel[]={
                {"impt_klics","xwaveLogo",KlicsList,"Import
KLICS",ImportKlics,NULL},
                {"impt_klicsSA","xwaveLogo",KlicsListSA,"Import KLICS
SA",ImpKlicsTestSA,NULL},
        };
        XtCallbackRec       main_call[]={
                {Select,(caddr_t)&selection[0]}, {NULL,NULL},
                {Select,(caddr_t)&selection[1]}, {NULL,NULL},
                {Select,(caddr_t)&selection[2]}, {NULL,NULL},
                {VideoClean,(caddr_t)NULL}, {NULL,NULL},
                {Quit,(caddr_t)NULL}, {NULL,NULL},
        }, save_call[]={
                {Select,(caddr_t)&save_sel[0]}, {NULL,NULL},
                {Select,(caddr_t)&save_sel[1]}, {NULL,NULL},
                {Select,(caddr_t)&save_sel[2]}, {NULL,NULL},
                {Select,(caddr_t)&save_sel[3]}, {NULL,NULL},
                {Select,(caddr_t)&save_sel[4]}, {NULL,NULL},
        }, impt_call[]={
                {Select,(caddr_t)&impt_sel[0]}, {NULL,NULL},
                {Select,(caddr_t)&impt_sel[1]}, {NULL,NULL},
        };
        Dprintf("InitMain\n");
        FillForm(form,ONE,items,widgets,NULL);
        main_shell=ShellWidget("xwave_main_sh",widgets[0],SW_menu,NULL,NULL);
        save_shell=ShellWidget("xwave_save_sh",main_shell,SW_menu,NULL,NULL);
        impt_shell=ShellWidget("xwave_impt_sh",main_shell,SW_menu,NULL,NULL);
        FillMenu(main_shell,MAIN_MENU,main_menu,main_widgets,main_call);
        FillMenu(save_shell,SAVE_MENU,save_menu,save_widgets,save_call);
        FillMenu(impt_shell,IMPT_MENU,impt_menu,impt_widgets,impt_call);
}
```

source/Klics5.c

```
/*
        Full still/video Knowles-Lewis Image Compression System utilising HVS
properties
        and delta-tree coding
*/

#include    "xwave.h"
#include        "Klics.h"
#include        <math.h>

extern Bits    bopen();
extern void    bclose(), bread(), bwrite(), bflush();

extern WriteKlicsHeader();

/* token modes (empty) */
#define         EMPTY       0
#define         CHANNEL_EMPTY          1
#define         OCTAVE_EMPTY   2
#define         LPF_EMPTY       3
#define FULL                4

typedef         struct _HistRec      {
        int     bits, octbits[3][5], lpf, activity, target, token[TOKENS], coeff[129];
        double          q_const;
} HistRec, *Hist; /* history record */

/*      Function Name:      Access
 *      Description:   Find index address from co-ordinates
```

```
 *      Arguments:   x, y - (x,y) co-ordinates
 *                   oct, sub, channel - octave, sub-band and channel co-ordinates
 *                   width - image data width
 *      Returns: index into vid->data[channel][][index]
 */

int     Access(x,y,oct,sub,width)

int     x, y, oct, sub, width;

{
        return(((x<<1)+(sub>>1)+width*((y<<1)+(1&sub)))<<oct);
}

/*      Function Name:      LastFrame
 *      Description:   Find last frame encoded
 *      Arguments:   z - index of current frame
 *                   hist - history records
 *      Returns:       index of previous frame
 */

int     LastFrame(z,hist)

int     z;
Hist    hist;

{
        int     i=z-1;

        while(hist[i].bits==0 && i>0) i--;
        return(i<0?0:i);
}
```

```
/*      Function Name:      Decide
 *      Description:  Calculate value representing the difference between new and old
blocks
 *      Arguments:    new, old - blocks to compare
 *                         mode - differencing algorithm {MAXIMUM | SIGABS |
SIGSQR}
 *      Returns:      difference value
 */

int     Decide(new,old,mode)

Block   new, old;
int     mode;

{
        int     X, Y, sigma=0;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++) {
                int     n_o=new[X][Y]-old[X][Y];

                switch(mode) {
                case MAXIMUM:
                        sigma=sigma>abs(n_o)?sigma:abs(n_o);
                        break;
                case SIGABS:
                        sigma+=abs(n_o);
                        break;
                case SIGSQR:
                        sigma+=n_o*n_o;
                        break;
                }
        }
```

```
        return(sigma);
}


/*      Function Name:      DecideDouble
 *      Description:   Calculates normal w.r.t differencing algorithm
 *      Arguments:     norm - normal value
 *                           mode - differencing algorithm {MAXIMUM | SIGABS |
SIGSQR}
 *      Returns:       new normal value
 */

double        DecideDouble(norm,mode)

double        norm;
int     mode;

{
        double        ret;

        switch(mode) {
        case MAXIMUM:
                ret=norm;
                break;
        case SIGABS:
                ret=4.0*norm;
                break;
        case SIGSQR:
                ret=4.0*norm*norm;
                break;
        }
        return(ret);
}
```

```
Boolean     Decision(new,old,norm,mode)

Block  new, old;
double      norm;
int    mode;

{
       return((double)Decide(new,old,mode)<=DecideDouble(norm,mode));
}

/*    Function Name:      Feedback
 *    Description:  Calculates new target activity from target bits and historical values
 *    Arguments:    hist - history records
 *                        curr - current frame
 *                        taps - size of history window
 *    Returns:      target activity
 */

int    Feedback(hist,curr,taps)

int    curr;
Hist   hist;
int    taps;

{
       int    prev=curr, i;
       double       ratio=0;

       for(i=0;i<taps && prev!=0;i++) {
              prev=LastFrame(prev,hist);

ratio+=(double)hist[prev].activity/(double)(hist[prev].bits-(prev==0?hist[0].lpf:0));
```

```
	}
	return((int)(ratio*(double)hist[curr].target/(double)i));
}

/*	Function Name:	Filter
 *	Description:	Calculates new q_const filtering historical values
 *	Arguments:	hist - history records
 *			curr - current frame
 *			taps - size of history window
 *			filter - index to filter
 *	Returns:	q_const
 */

double		Filter(hist,curr,taps,filter)

int	curr;
Hist	hist;
int	taps, filter;

{
	double		mac=hist[curr].q_const, sum=1.0, coeff=1.0;
	int	i, prev=curr;

	for(i=0;i<taps && prev!=0;i++) {
		prev=LastFrame(prev,hist);
		coeff=filter==0?0:coeff/2.0;
		mac+=hist[prev].q_const*coeff;
		sum+=coeff;
	}
	return(mac/sum);
}
```

```
/*      Function Name:    Huffman
 *      Description:  Calculates the number of bits for the Huffman code representing
level
 *      Arguments:    level - level to be encoded
 *      Returns:      number of bits in codeword
 */

int     Huffman(level)

int     level;

{
        return(level==0?2:(abs(level)<3?3:1+abs(level)));
}

/*      Function Name:      HuffCode
 *      Description:  Generates Huffman code representing level
 *      Arguments:    level - level to be encoded
 *      Returns:      coded bits in char's
 */

unsigned char *HuffCode(level)

int     level;

{
        unsigned char *bytes=(unsigned char *)MALLOC((7+Huffman(level))/8);

        bytes[0]=(abs(level)<3?abs(level):3)|(level<0?4:0);
        if (abs(level)>2) {
                int     index=(7+Huffman(level))/8-1;
```

```
			bytes[index]=bytes[index]|(1<<(Huffman(level)-1)%8);
		}
		return(bytes);
}

unsigned char *CodeInt(number,bits)

int	number, bits;

{
	int	len=(7+bits)/8;
	unsigned char *bytes=(unsigned char *)MALLOC(len);
	int	byte;

	for(byte=0;byte<len;byte++) {
		bytes[byte]=0xff&number;
		number=number>>8;
	}
	return(bytes);
}

int	ReadInt(bits,bfp)

int	bits;
Bits	bfp;

{
	int	len=(7+bits)/8;
	unsigned char bytes[len];
	int	byte, number=0;

	bread(bytes,bits,bfp);
```

```
    for(byte=0;byte<len;byte++)
        number=number|((int)bytes[byte]<<byte*8);
    number=(number<<sizeof(int)*8-bits)>>sizeof(int)*8-bits;
    return(number);
}

/*  Function Name:   HuffRead
 *  Description:  Read Huffman encoded number from binary file
 *  Arguments:    bfp - binary file pointer
 *  Returns:      decoded level
 */

int     HuffRead(bfp)

Bits    bfp;

{
    int     value;
    unsigned char       byte;
    Boolean     negative=False;

    bread(&byte,2,bfp);
    value=(int)byte;
    if (byte=='\0') return(0);
    else {
        bread(&byte,1,bfp);
        negative=(byte!='\0');
    }
    if (value<3) return(negif(negative,value));
    for(byte='\0';byte=='\0';value++) bread(&byte,1,bfp);
    return(negif(negative,value-1));
}
```

```
/*      Function Name:      Quantize
 *      Description:    RM8 style quantizer
 *      Arguments:      data - unquantised number
 *                              q - quantizing divisor
 *                              level - quantised to level
 *      Returns:        quantized data & level
 */

int     Quantize(data,q,level)

int     data, q, *level;

{
        int     mag_level=abs(data)/q;

        *level=negif(data<0,mag_level);
        return(negif(data<0,mag_level*q+(mag_level!=0?(q-1)>>1:0)));
}

/*      Function Name:      Proposed
 *      Description:    Calculates proposed block values
 *      Arguments:      pro - proposed block
 *                              lev - proposed block quantized levels
 *                              old, new - old and new block values
 *                              decide - decision algorithm
 *                              norms - HVS normals
 *      Returns:        new==0, proposed values (pro) and levels (lev)
 */

Boolean     Proposed(pro,lev,old,new,decide,norms)

Block  pro, lev, old, new;
```

```
int     decide;
double          norms[3];

{
        Block  zero_block={{0,0},{0,0}};
        int     X, Y, step=norms[0]<1.0?1:(int)norms[0];
        Boolean         zero=Decision(new,zero_block,norms[1],decide);

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)

pro[X][Y]=zero?0:old[X][Y]+Quantize(new[X][Y]-old[X][Y],step,&(lev[X][Y]));
        return(zero);
}

/*      Function Name:      ZeroCoeffs
 *      Description:  Zero out video data
 *      Arguments:    data - image data
 *                          addr - addresses
 *      Returns:        zeros data[addr[][]]
 */

void    ZeroCoeffs(data,addr)

short   *data;
Block  addr;

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
                data[addr[X][Y]]=0;
}
```

```
/*	Function Name:	BlockZero
 *	Description:	Test if all block values are zero
 *	Arguments:	block - block under test
 *	Returns:	block==0
 */

Boolean	BlockZero(block)

Block	block;

{
	int	X, Y;
	Boolean	zero=True;

	for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
		if (block[X][Y]!=0) zero=False;
	return(zero);
}

/*	Function Name:	SendToken
 *	Description:	Increments token frequency
 *	Arguments:	token - token to be transmitted
 *			channel, sub, oct - co-ordinates
 *			ctrl - control record for compresssion
 *			hist - history record
 *			empty - zero state {EMPTY | CHANNEL_EMPTY |
OCTAVE_EMPTY | LPF_EMPTY | FULL}
 *			branch - branch of tree (0-3)
 *	Returns:	encodes token
 */

void	SendToken(token,channel,sub,oct,ctrl,hist,empty,branch)
```

```
int     token, channel, sub, oct, *empty, branch;
CompCtrl      ctrl;
Hist    hist;

{
        int     full=FULL, i;
        String
token_name[TOKENS]={"ZERO_STILL","NON_ZERO_STILL","BLOCK_SAME","ZE
RO_VID","BLOCK_CHANGE",

"LOCAL_ZERO","LOCAL_NON_ZERO","CHANNEL_ZERO","CHANNEL_NON_ZE
RO","OCT_ZERO","OCT_NON_ZERO",

"LPF_ZERO","LPF_NON_ZERO","LPF_LOC_ZERO","LPF_LOC_NON_ZERO"};

        switch(*empty) {
        case EMPTY:
                if (token!=ZERO_STILL && token!=BLOCK_SAME) {

SendToken(LOCAL_NON_ZERO,channel,sub,oct,ctrl,hist,&full,branch);
                        for(i=0;i<channel;i++)
SendToken(CHANNEL_ZERO,i,sub,oct,ctrl,hist,&full,branch);
                        *empty=CHANNEL_EMPTY;
                        SendToken(token,channel,sub,oct,ctrl,hist,empty,branch);
                }
                break;
        case CHANNEL_EMPTY:
                if (token!=ZERO_STILL && token!=BLOCK_SAME) {

SendToken(CHANNEL_NON_ZERO,channel,sub,oct,ctrl,hist,&full,branch);
                        for(i=1;i<sub;i++)
SendToken(token==NON_ZERO_STILL?ZERO_STILL:BLOCK_SAME,channel,i,oct,ct
```

```
rl,hist,&full,branch);
                        *empty=FULL;
                        SendToken(token,channel,sub,oct,ctrl,hist,empty,branch);
                }
                break;
        case OCTAVE_EMPTY:
                if (token!=ZERO_STILL && token!=BLOCK_SAME) {

SendToken(OCT_NON_ZERO,channel,sub,oct,ctrl,hist,&full,branch);
                        for(i=0;i<branch;i++)
SendToken(token==NON_ZERO_STILL?ZERO_STILL:BLOCK_SAME,channel,sub,oc
t,ctrl,hist,&full,branch);
                        *empty=FULL;
                        SendToken(token,channel,sub,oct,ctrl,hist,empty,branch);
                }
                break;
        case LPF_EMPTY:
                if (token!=LPF_ZERO) {

SendToken(LPF_LOC_NON_ZERO,channel,sub,oct,ctrl,hist,&full,branch);
                        for(i=0;i<channel;i++)
SendToken(LPF_ZERO,i,sub,oct,ctrl,hist,&full,branch);
                        *empty=FULL;
                        SendToken(token,channel,sub,oct,ctrl,hist,empty,branch);
                }
                break;
        case FULL:
                Dprintf("%s\n",token_name[token]);
                hist->token[token]++;
                hist->bits+=token_bits[token];
                hist->octbits[channel][oct]+=token_bits[token];
                if (ctrl->bin_switch)
```

```
bwrite(&token_codes[token],token_bits[token],ctrl->bfp);
            break;
        }
}

/*      Function Name:      ReadBlock
 *      Description:  Read block from video
 *      Arguments:    new, old, addr - new and old blocks and addresses
 *                          x, y, z, oct, sub, channel - co-ordinates of block
 *                          ctrl - compression control record
 *      Returns:      block values
 */

void    ReadBlock(new,old,addr,x,y,z,oct,sub,channel,ctrl)

Block   new, old, addr;
int     x, y, z, oct, sub, channel;
CompCtrl        ctrl;

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++) {

addr[X][Y]=Access((x<<1)+X,(y<<1)+Y,oct,sub,Size(ctrl->src,channel,0));
                new[X][Y]=(int)ctrl->src->data[channel][z][addr[X][Y]];
                old[X][Y]=(int)ctrl->dst->data[channel][z][addr[X][Y]];
        }
}

/*      Function Name:      CalcNormals
 *      Description:  Calculates HVS weighted normals
```

```
*	Arguments:	ctrl -	compression control record
*				oct, sub, channel - co-ordinates
*				norms - pre-initialised normals
*	Returns:	weighted normals
*/

void	CalcNormals(ctrl,oct,sub,channel,norms)

CompCtrl	ctrl;
int	oct, sub, channel;
double		norms[3];

{
	Video	vid=ctrl->dst;
	int	norm, base_oct=oct+(vid->type==YUV &&
channel!=0?vid->trans.wavelet.space[0]-vid->trans.wavelet.space[1]:0)+(sub==0?1:0)
;

	for(norm=0;norm<3;norm++) {
		if (norm!=0) norms[norm] *= ctrl->quant_const;
		norms[norm] *=
ctrl->base_factors[base_oct]*(sub==3?ctrl->diag_factor:1.0);
		if (channel!=0) norms[norm] *= ctrl->chrome_factor;
		norms[norm] *=(double)(1<<vid->precision);
	}
}

/*	Function Name:	MakeDecisions
*	Description:	Decide on new compression mode from block values
*	Arguments:	old, new, pro - block values
*				zero - zero flag for new block
*				norms - HVS normals
```

```
*                       mode - current compression mode
*                       decide - comparison algorithm
*    Returns:      new compression mode
*/

int     MakeDecisions(old,new,pro,zero,norms,mode,decide)

Block  new, old, pro;
Boolean       zero;
double        norms[3];
int     mode, decide;

{
        Block  zero_block={{0,0},{0,0}};
        int     new_mode, np=Decide(new,pro,decide), no=Decide(new,old,decide);

        if (np<no && (double)no>DecideDouble(norms[mode==STILL?1:2],decide)
&& !zero)
                new_mode=mode==STILL ||
(double)Decide(old,zero_block,decide)<=DecideDouble(norms[1],decide)?STILL:SEND;
        else new_mode=mode==SEND && np<no && zero?VOID:STOP;
        return(new_mode);
}

int     MakeDecisions2(old,new,pro,lev,zero,norms,mode,decide)

Block  new, old, pro, lev;
Boolean       zero;
double        norms[3];
int     mode, decide;

{
```

```
        Block  zero_block={{0,0},{0,0}};
        int    new_mode=mode==STILL || BlockZero(old)?STILL:SEND,
                    np=Decide(new,pro,decide), no=Decide(new,old,decide);

        if (new_mode==STILL) new_mode=np>=no || zero ||
BlockZero(lev)?STOP:STILL;
        else new_mode=zero && np<no?VOID:np>=no ||
Decision(new,old,norms[2],decide) || BlockZero(lev)?STOP:SEND;
        return(new_mode);
}

/*      Function Name:      UpdateCoeffs
 *      Description:   Encode proposed values and write data
 *      Arguments:     pro, lev, addr - proposed block, levels and addresses
 *                          z, channel, oct - co-ordinates
 *                          ctrl - compression control record
 *                          hist - history record
 *      Returns:       alters ctrl->dst->data[channel][z][addr[][]]
 */

void    UpdateCoeffs(pro,lev,addr,z,channel,oct,ctrl,hist)

Block  pro, lev, addr;
int    z, channel, oct;
CompCtrl ctrl;
Hist   hist;

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++) {
                int     bits=Huffman(lev[X][Y]),
```

```
                    level=abs(lev[X][Y]);

            ctrl->dst->data[channel][z][addr[X][Y]]=(short)pro[X][Y];
            hist->coeff[level>128?128:level]++;
            hist->bits+=bits;
            hist->octbits[channel][oct]+=bits;
            if (ctrl->bin_switch) {
                unsigned char       *bytes=HuffCode(lev[X][Y]);

                bwrite(bytes,bits,ctrl->bfp);
                XtFree(bytes);
            }
        }
}

/*      Function Name:      SendTree
 *      Description:    Encode tree blocks
 *      Arguments:      prev_mode - compression mode
 *                              x, y, z, oct, sub, channel - co-ordinates
 *                              ctrl - compression control record
 *                              hist - history records
 *                              empty - token mode
 *                              branch - tree branch number
 *      Returns:        active block indicator
 */

Boolean     SendTree(prev_mode,x,y,z,oct,sub,channel,ctrl,hist,empty,branch)

int     prev_mode, x, y, z, oct, sub, channel, *empty, branch;
CompCtrl        ctrl;
Hist    hist;
```

```
{
        Block  addr, old, new, pro, lev;
        int    new_mode, X, Y;
        double
norms[3]={ctrl->quant_const,ctrl->thresh_const,ctrl->cmp_const}; /* quant, thresh,
compare */
        Boolean       active=False;

        ReadBlock(new,old,addr,x,y,z,oct,sub,channel,ctrl);
        if (prev_mode!=VOID) {
                Boolean       zero;

                CalcNormals(ctrl,oct,sub,channel,norms);
                zero=Proposed(pro,lev,old,new,ctrl->decide,norms);
/*
new_mode=MakeDecisions(old,new,pro,zero,norms,prev_mode,ctrl->decide);*/

new_mode=MakeDecisions2(old,new,pro,lev,zero,norms,prev_mode,ctrl->decide);
                switch(new_mode) {
                case STOP:

/*SendToken(prev_mode==STILL?ZERO_STILL:BLOCK_SAME,channel,sub,oct,ctrl,h
ist,empty,branch);*/
                        SendToken(prev_mode==STILL ||
BlockZero(old)?ZERO_STILL:BLOCK_SAME,channel,sub,oct,ctrl,hist,empty,branch);
                        break;
                case STILL:
                case SEND:
                        active=True;

/*SendToken(prev_mode==STILL?NON_ZERO_STILL:BLOCK_CHANGE,channel,sub
,oct,ctrl,hist,empty,branch);*/
```

```
                    SendToken(prev_mode==STILL ||
BlockZero(old)?NON_ZERO_STILL:BLOCK_CHANGE,channel,sub,oct,ctrl,hist,empty,
branch);
                    UpdateCoeffs(pro,lev,addr,z,channel,oct,ctrl,hist);
                    break;
            case VOID:
                    SendToken(ZERO_VID,channel,sub,oct,ctrl,hist,empty,branch);
                    ZeroCoeffs(ctrl->dst->data[channel][z],addr);
                    break;
            }
        } else {
            if (BlockZero(old)) new_mode=STOP;
            else {
                    ZeroCoeffs(ctrl->dst->data[channel][z],addr);
                    new_mode=VOID;
            }
        }
        if (oct>0 && new_mode!=STOP) {
            int     mt=OCTAVE_EMPTY, full=FULL;

            Dprintf("x=%d, y=%d, oct=%d sub=%d mode
%d\n",x,y,oct,sub,new_mode);
            for(Y=0;Y<2;Y++) for(X=0;X<2;X++)

(void)SendTree(new_mode,x*2+X,y*2+Y,z,oct-1,sub,channel,ctrl,hist,&mt,X+2*Y);
            if (mt==OCTAVE_EMPTY && new_mode!=VOID)
SendToken(OCT_ZERO,channel,sub,oct,ctrl,hist,&full,0);
        }
        return(active);
}

/*      Function Name:      SendLPF
```

```
*       Description:  Encode LPF sub-band
*       Arguments:    mode - compression mode
*                           z -     frame number
*                           ctrl - compression control record
*                           hist - history records
*       Returns:      encodes data
*/

void    SendLPF(mode,z,ctrl,hist)

CompCtrl     ctrl;
int     mode, z;
Hist    hist;

{
        Block  new, old, pro, lev, addr;
        int     channel, channels=ctrl->src->type==MONO?1:3, x, y, full=FULL,
                        octs_lum=ctrl->src->trans.wavelet.space[0],

size[2]={Size(ctrl->src,0,0)>>octs_lum+1,Size(ctrl->src,0,1)>>octs_lum+1};

        for(y=0;y<size[1];y++) for(x=0;x<size[0];x++) {
                int     empty=LPF_EMPTY;

        for(channel=0;channel<channels;channel++) {
                int     octs=ctrl->src->trans.wavelet.space[ctrl->src->type==YUV
&& channel!=0?1:0],
                                new_mode, X, Y, step, value, bits=0;
                double
norms[3]={ctrl->quant_const,ctrl->thresh_const,ctrl->cmp_const};

                CalcNormals(ctrl,octs-1,0,channel,norms);
```

```
            step=norms[0]<1.0?1:(int)norms[0];
            for(bits=0,
value=((1<<8+ctrl->dst->precision)-1)/step;value!=0;bits++)
                value=value>>1;
            ReadBlock(new,old,addr,x,y,z,octs-1,0,channel,ctrl);

            /* Proposed */
            for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)

pro[X][Y]=old[X][Y]+Quantize(new[X][Y]-old[X][Y],step,&(lev[X][Y]));

            /* MakeDecisions */

new_mode=mode==STILL?STILL:Decision(new,old,norms[2],ctrl->decide) ||
BlockZero(lev)?STOP:SEND;

            switch(new_mode) {
            case SEND:
                SendToken(LPF_NON_ZERO,channel,0,octs,ctrl,hist,&empty,0);
                UpdateCoeffs(pro,lev,addr,z,channel,octs,ctrl,hist);
            break;
            case STILL:
                for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++) {
                    ctrl->dst->data[channel][z][addr[X][Y]]=(short)pro[X][Y];
                    hist->bits+=bits;
                    hist->octbits[channel][octs]+=bits;
                    if (ctrl->bin_switch) {
                        unsigned char *bytes=CodeInt(lev[X][Y],bits);

                        bwrite(bytes,bits,ctrl->bfp);
                        XtFree(bytes);
                    }
```

```
                }
                break;
            case STOP:
                SendToken(LPF_ZERO,channel,0,octs,ctrl,hist,&empty,0);
                break;
            }
        }
        if (mode!=STILL && empty==LPF_EMPTY)
SendToken(LPF_LOC_ZERO,channel,0,octs_lum,ctrl,hist,&full,0);
        }
        hist->lpf=hist->bits;
}

/*      Function Name:   LookAhead
 *      Description:  Examine base of tree to calculate new quantizer value
 *      Arguments:    z - frame number
 *                       ctrl - compression control record
 *                       hist - history records
 *      Returns:      calculates new ctrl->quant_const
 */

void    LookAhead(z,ctrl,hist)

CompCtrl    ctrl;
int     z;
Hist    hist;

{
            int     x, y, sub, index, thresh[HISTO], decide=ctrl->decide, act,
                       taract=Feedback(hist,z,ctrl->feedback),
                       octs=ctrl->src->trans.wavelet.space[0],
```

```
size[2]={Size(ctrl->src,0,0)>>1+octs,Size(ctrl->src,0,1)>>1+octs};
            Block  new, old, addr;
            double       old_quant=ctrl->quant_const;

            ctrl->quant_const=1.0;
            for(index=0;index<HISTO;index++) thresh[index]=0;
            for(y=0;y<size[1];y++) for(x=0;x<size[0];x++)
for(sub=1;sub<4;sub++) {
                double       q_thresh[3],
norms[3]={ctrl->quant_const,ctrl->thresh_const,ctrl->cmp_const};
                Block  zero_block={{0,0},{0,0}};

                ReadBlock(new,old,addr,x,y,z,octs-1,sub,0,ctrl);
                CalcNormals(ctrl,octs-1,sub,0,norms);

q_thresh[1]=(double)Decide(new,zero_block,decide)/DecideDouble(norms[1],decide);

q_thresh[2]=(double)Decide(new,old,decide)/DecideDouble(norms[2],decide);
                if (BlockZero(old)) q_thresh[0]=q_thresh[1];
                else q_thresh[0]=q_thresh[2]<q_thresh[1]?q_thresh[2]:q_thresh[1];
                if (ctrl->decide==SIGSQR) q_thresh[0]=sqrt(q_thresh[0]);

index=(int)((q_thresh[0]-old_quant+HISTO_DELTA)*HISTO/(HISTO_DELTA*2));
                index=index<0?0:index>HISTO-1?HISTO-1:index;
                thresh[index]++;
            }
            for(index=HISTO-1, act=0;index>=0 && act<taract;index--)
act+=thresh[index];

ctrl->quant_const=(double)(index+1)*HISTO_DELTA*2.0/HISTO+old_quant-HISTO_
DELTA;
            ctrl->quant_const=ctrl->quant_const<0.0?0.0:ctrl->quant_const;
```

```
		Dprintf("Target bits %d act %d (real %d) adjust q_const to
%3.2f\n",hist[z].target,taract,act,ctrl->quant_const);
		hist[z].q_const=ctrl->quant_const;
		ctrl->quant_const=Filter(hist,z,ctrl->feedback,ctrl->filter);
		Dprintf("Post filtering q_const to %3.2f\n",ctrl->quant_const);
		if (ctrl->bin_switch) {
			unsigned char *bytes=CodeInt(index+1-HISTO/2,HISTO_BITS);

			bwrite(bytes,HISTO_BITS,ctrl->bfp);
			XtFree(bytes);
		}
}

/*	Function Name:	CompressStats
 *	Description:	Compile compression statistics
 *	Arguments:	ctrl - compression control record
 *			hist - history records
 *	Returns:	plot graphs
 */

void	CompressStats(ctrl,hist)

CompCtrl	ctrl;
Hist	hist;

{
	FILE	*fp_token, *fp_coeff, *fp_log, *fopen();
	char	file_name[STRLEN];
	int	channel, z, i, sigma;


sprintf(file_name,"%s%s/%s.token%s\0",global->home,PLOT_DIR,ctrl->stats_name,P
```

```
LOT_EXT);
        fp_token=fopen(file_name,"w");

sprintf(file_name,"%s%s/%s.coeff%s\0",global->home,PLOT_DIR,ctrl->stats_name,PL
OT_EXT);
        fp_coeff=fopen(file_name,"w");

sprintf(file_name,"%s%s/%s.log%s\0",global->home,PLOT_DIR,ctrl->stats_name,PLO
T_EXT);
        fp_log=fopen(file_name,"w");
        fprintf(fp_token,"\"Tokens %s\n",ctrl->name);
        for(i=0;i<TOKENS;i++) {
                sigma=0;
                for(z=0;z<ctrl->src->size[2];z++) sigma+=hist[z].token[i];
                fprintf(fp_token,"%d %d\n",i,sigma);
        }
        fprintf(fp_coeff,"\"Coeffs %s\n",ctrl->name);
        for(i=0;i<129;i++) {
                sigma=0;
                for(z=0;z<ctrl->src->size[2];z++) sigma+=hist[z].coeff[i];
                fprintf(fp_coeff,"%d %d\n",i,sigma);
        }
        for(i=0;i<5;i++) {
                String  titles[5]={"treebits","activity","quant","bits","ratio"};

                fprintf(fp_log,"\n\"%s\n",titles[i]);
                for(z=0;z<ctrl->src->size[2];z++)
                        switch(i) {
                        case 0: fprintf(fp_log,"%d %d\n",z,hist[z].bits-hist[z].lpf);
                                break;
                        case 1: fprintf(fp_log,"%d %d\n",z,hist[z].activity);
                                break;
```

```
                    case 2: fprintf(fp_log,"%d %f\n",z,hist[z].q_const);
                            break;
                    case 3:     fprintf(fp_log,"%d %d\n",z,hist[z].bits);
                            break;
                    case 4:     fprintf(fp_log,"%d
%f\n",z,(double)(hist[z].bits-(z==0?hist[z].lpf:0))/(double)hist[z].activity);
                            break;
                    }
        }
        for(channel=0;channel<(ctrl->src->type==MONO?1:3);channel++) {
                int     octs=ctrl->src->trans.wavelet.space[ctrl->src->type==YUV
&& channel!=0?1:0];

        for(i=0;i<=octs;i++) {
                fprintf(fp_log,"\n\"channel %d oct %d\n",channel,i);
                for(z=0;z<ctrl->src->size[2];z++)
                        fprintf(fp_log,"%d %d\n",z,hist[z].octbits[channel][i]);
        }
        }
        fclose(fp_token); fclose(fp_coeff); fclose(fp_log);
}

/*      Function Name:      CopyFrame
 *      Description:    Copy frame or zero
 *      Arguments:      vid - video
 *                          from, to - source and destination frame numbers
 *                          zero - zero out flag
 *      Returns:        alters video->data
 */

void    CopyFrame(vid,from,to,zero)
```

```
Video   vid;
int     from, to;
Boolean     zero;

{
        int     i, channel;

        for(channel=0;channel<(vid->type==MONO?1:3);channel++) {
                int     size=Size(vid,channel,0)*Size(vid,channel,1);

                for(i=0;i<size;i++)
                        vid->data[channel][to][i]=zero?0:vid->data[channel][from][i];
        }
}

/*      Function Name:      CompressFrame
 *      Description:  Compress a Frame
 *      Arguments:    ctrl - compression control record
 *                          z - frame number
 *                          hist - history records
 *                          target - target bits
 */

void    CompressFrame(ctrl,z,hist,target)

CompCtrl    ctrl;
int     z, target;
Hist    hist;

{
        Video   src=ctrl->src, dst=ctrl->dst;
        int     sub, channel, x, y, mode=ctrl->stillvid || z==0?STILL:SEND,
```

```
                octs_lum=src->trans.wavelet.space[0],

size[2]={Size(src,0,0)>>1+octs_lum,Size(src,0,1)>>1+octs_lum};

        NewFrame(dst,z);
        CopyFrame(dst,z-1,z,ctrl->stillvid || z==0);
        GetFrame(src,z);
        hist[z].target=target;
        if (z!=0 && ctrl->auto_q) LookAhead(z,ctrl,hist);
        SendLPF(mode,z,ctrl,&hist[z]);
        Dprintf("LPF bits %d\n",hist[z].lpf);
        hist[z].q_const=ctrl->quant_const;
        for(y=0;y<size[1];y++) for(x=0;x<size[0];x++) {
                int     empty=EMPTY, full=FULL;

                for(channel=0;channel<(dst->type==MONO?1:3);channel++) {
                        int     octs=src->trans.wavelet.space[src->type==YUV &&
channel!=0?1:0];

                        for(sub=1;sub<4;sub++) {
                                Boolean
active=SendTree(mode,x,y,z,octs-1,sub,channel,ctrl,&hist[z],&empty,0);

                                hist[z].activity+=channel==0 && active;
                        }
                        switch(empty) {
                        case FULL:
                                empty=CHANNEL_EMPTY;
                                break;
                        case CHANNEL_EMPTY:
                                SendToken(CHANNEL_ZERO,channel,sub,octs-1,ctrl,&hist[z],&full,0)
                                break;
```

```
                        }
                }
                if (empty==EMPTY)
SendToken(LOCAL_ZERO,channel,sub,octs_lum-1,ctrl,&hist[z],&full,0);
        }
        Dprintf("Activity: %d\n",hist[z].activity);
        FreeFrame(src,z);
}

/*      Function Name:      SkipFrame
 *      Description:   Shuffle frame data as if current frame was skipped
 *      Arguments:     vid - video
 *                          z - frame number
 *      Returns:       alters vid->data
 */

void    SkipFrame(vid,z)

Video vid;
int     z;

{
        NewFrame(vid,z);
        CopyFrame(vid,z-1,z,False);
        if (z>1) {
                GetFrame(vid,z-2);
                CopyFrame(vid,z-2,z-1,False);
                FreeFrame(vid,z-2);
        }
}

/*      Function Name:      CompressCtrl
```

```
 *      Description:  Perform KLICS on a video
 *      Arguments:    w - Xaw widget
 *                          closure - compression control record
 *                          call_data - NULL
 *      Returns:      compressed video
 */

void    CompressCtrl(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;

{
        CompCtrl        ctrl=(CompCtrl)closure;
        int     sigma_bits, frame_count, z, i, buffer=0, frames=ctrl->src->size[2],
                        bpf_in=(64000*ctrl->bitrate)/ctrl->src->rate,
                        bpf_out=(int)((double)(64000*ctrl->bitrate)/ctrl->fps);
        FILE    *fopen();
        char    file_name[STRLEN];
        HistRec         hist[frames];
        Message         msg=NewMessage(NULL,60);

        msg->rows=frames>10?11:frames+(frames==1?0:1); msg->cols=30;
        if (global->batch==NULL) {
                XtCallbackRec           callbacks[]={
                        {CloseMessage,(caddr_t)msg}, {NULL,NULL},
                };


MessageWindow(FindWidget("frm_compress",w),msg,"KLICS",True,callbacks);
        }
        Dprintf("CompressCtrl\n");
```

```
	if (ctrl->src->type==YUV &&
(ctrl->src->trans.wavelet.space[0]!=ctrl->src->trans.wavelet.space[1]+ctrl->src->U
Vsample[0] || ctrl->src->UVsample[0]!=ctrl->src->UVsample[1])) {
		Eprintf("Y-UV octaves mis-matched. Check UV-sample");
		return;
	}
	ctrl->dst=CopyHeader(ctrl->src);
	strcpy(ctrl->dst->name,ctrl->name);
	if (ctrl->dst->disk) SaveHeader(ctrl->dst);
	if (ctrl->bin_switch) {

sprintf(file_name,"%s%s/%s%s\0",global->home,KLICS_DIR,ctrl->bin_name,KLICS_
EXT);
		ctrl->bfp=bopen(file_name,"w");
		/* Write some sort of header */
		WriteKlicsHeader(ctrl);
	}
	for(z=0;z<frames;z++) {
		hist[z].bits=0;
		hist[z].lpf=0;
		hist[z].activity=0;
		hist[z].target=0;
		for(i=0;i<5;i++) hist[z].octbits[0][i]=0;
		for(i=0;i<5;i++) hist[z].octbits[1][i]=0;
		for(i=0;i<5;i++) hist[z].octbits[2][i]=0;
		for(i=0;i<TOKENS;i++) hist[z].token[i]=0;
		for(i=0;i<129;i++) hist[z].coeff[i]=0;
		hist[z].q_const=0.0;
	}
	for(z=0;z<frames;z++) {
		if (z==0 || !ctrl->buf_switch) {
			CompressFrame(ctrl,z,hist,bpf_out);
```

```
			buffer=3200*ctrl->bitrate+bpf_in;
		} else {
			Boolean		no_skip;

			buffer-=bpf_in;
			buffer=buffer<0?0:buffer;
			no_skip=buffer<6400*ctrl->bitrate; /* H.261 buffer size */
			if (ctrl->bin_switch) bwrite(&no_skip,1,ctrl->bfp);
			if (no_skip) {
				CompressFrame(ctrl,z,hist,bpf_out/*+bpf_out/2-buffer*/);
				buffer+=hist[z].bits;
			} else SkipFrame(ctrl->dst,z);
		}
		if (z>0) {
			SaveFrame(ctrl->dst,z-1);
			FreeFrame(ctrl->dst,z-1);
		}
		Mprintf(msg,"%s%03d: %d
bits\n",ctrl->dst->name,z+ctrl->src->start,hist[z].bits);
		Mflush(msg);
	}
	SaveFrame(ctrl->dst,ctrl->src->size[2]-1);
	FreeFrame(ctrl->dst,ctrl->src->size[2]-1);
	if (ctrl->bin_switch) { bflush(ctrl->bfp); bclose(ctrl->bfp); }
	if (ctrl->stats_switch) CompressStats(ctrl,hist);
	Dprintf("Compression Complete\n");
	sigma_bits=0, frame_count=0;
	for(z=0;z<ctrl->src->size[2];z++) {
		sigma_bits+=hist[z].bits;
		if (hist[z].bits!=0) frame_count++;
	}
	if (ctrl->buf_switch) {
```

```
            Dprintf("Buffer contains %d bits\n",buffer-bpf_in);
            Dprintf("Frame Rate %4.1f
Hz\n",(double)(ctrl->src->rate*(frame_count-1))/(double)(ctrl->src->size[2]-1));
        }
        if (frames>1) {
            Mprintf(msg,"Total: %d bits\n",sigma_bits);
            Mflush(msg);
        }
        ctrl->dst->next=global->videos;
        global->videos=ctrl->dst;
}

/*      Function Name:      BatchCompCtrl
 *      Description:   Batch interface to CompressCtrl
 */

void    BatchCompCtrl(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        CompCtrl     ctrl=(CompCtrl)closure;

        if (ctrl->src==NULL) ctrl->src=FindVideo(ctrl->src_name,global->videos);
        CompressCtrl(w,closure,call_data);
}

/*      Function Name:      InitCompCtrl
 *      Description:   Initialise the compression control record
 *      Arguments:     name - name of the source video
 *      Returns:       compression control record
```

```
*/

CompCtrl    InitCompCtrl(name)

String  name;

{
        CompCtrl    ctrl=(CompCtrl)MALLOC(sizeof(CompCtrlRec));
        int     i;

        ctrl->decide=SIGABS;
        ctrl->feedback=4;
        ctrl->filter=0;
        ctrl->stillvid=True;
        ctrl->stats_switch=False;
        ctrl->auto_q=True;
        ctrl->buf_switch=True;
        ctrl->bin_switch=False;
        ctrl->cmp_const=0.9;
        ctrl->thresh_const=0.6;
        ctrl->quant_const=8.0;
        ctrl->fps=30.0;
        ctrl->bitrate=1;
        for(i=0;i<5;i++) {
                double      defaults[5]={1.0,0.32,0.16,0.16,0.16};

                ctrl->base_factors[i]=defaults[i];
        }
        ctrl->diag_factor=1.4142136;
        ctrl->chrome_factor=2.0;
        strcpy(ctrl->src_name,name);
        strcpy(ctrl->name,name);
```

```
        strcpy(ctrl->stats_name,name);
        strcpy(ctrl->bin_name,name);
        return(ctrl);
}

/*      Function Name:      Compress
 *      Description:   X Interface to CompressCtrl
 */

#define        COMP_ICONS       25
#define        VID_ICONS  15

void   Compress(w,closure,call_data)

Widget         w;
caddr_t        closure, call_data;

{
        Video  video=(Video)closure;
        CompCtrl       ctrl=InitCompCtrl(video->name);
        int      i, space=video->trans.wavelet.space[0]+1;
        NumInput       num_inputs=(NumInput)MALLOC(2*sizeof(NumInputRec));
        FloatInput     flt_inputs=(FloatInput)MALLOC(6*sizeof(FloatInputRec)),

oct_inputs=(FloatInput)MALLOC(space*sizeof(FloatInputRec));
        Message        msg=NewMessage(ctrl->name,NAME_LEN),
                       msg_bin=NewMessage(ctrl->bin_name,NAME_LEN),
                       msg_stats=NewMessage(ctrl->stats_name,NAME_LEN);
        XtCallbackRec          destroy_call[]={
                {Free,(caddr_t)ctrl},
                {Free,(caddr_t)num_inputs},
                {Free,(caddr_t)flt_inputs},
```

```
		{Free,(caddr_t)oct_inputs},
		{CloseMessage,(caddr_t)msg},
		{CloseMessage,(caddr_t)msg_bin},
		{CloseMessage,(caddr_t)msg_stats},
		{NULL,NULL},
	};
	Widget		parent=FindWidget("frm_compress",XtParent(w)),
			shell=ShellWidget("klics",parent,SW_below,NULL,destroy_call),
			form=FormatWidget("klics_form",shell),

dec_shell=ShellWidget("klics_cng_dec",shell,SW_menu,NULL,NULL), dec_widgets[3],

filt_shell=ShellWidget("klics_cng_filt",shell,SW_menu,NULL,NULL), filt_widgets[2],
			widgets[COMP_ICONS], vid_widgets[VID_ICONS],
oct_widgets[space*2];
	FormItem	items[]={
		{"klics_cancel","cancel",0,0,FW_icon,NULL},
		{"klics_confirm","confirm",1,0,FW_icon,NULL},
		{"klics_title","Compress a video",2,0,FW_label,NULL},
		{"klics_vid_lab","Video Name:",0,3,FW_label,NULL},
		{"klics_vid",NULL,4,3,FW_text,(String)msg},

		{"klics_stats_lab","Statistics:",0,4,FW_label,NULL},
		{"klics_stats",NULL,4,4,FW_yn,(String)&ctrl->stats_switch},
		{"klics_stats_name",NULL,7,4,FW_text,(String)msg_stats},
		{"klics_bin_lab","KLICS File:",0,6,FW_label,NULL},
		{"klics_bin",NULL,4,6,FW_yn,(String)&ctrl->bin_switch},

		{"klics_bin_name",NULL,10,6,FW_text,(String)msg_bin},
		{"klics_dec_lab","Decision:",0,9,FW_label,NULL},
		{"klics_dec_btn","SigmaAbs",4,9,FW_button,"klics_cng_dec"},
		{"klics_qn_float",NULL,0,12,FW_float,(String)&flt_inputs[0]},
```

```
        {"klics_qn_scroll",NULL,4,12,FW_scroll,(String)&flt_inputs[0]},
        {"klics_th_float",NULL,0,14,FW_float,(String)&flt_inputs[1]},
        {"klics_th_scroll",NULL,4,14,FW_scroll,(String)&flt_inputs[1]},
        {"klics_cm_float",NULL,0,16,FW_float,(String)&flt_inputs[2]},
        {"klics_cm_scroll",NULL,4,16,FW_scroll,(String)&flt_inputs[2]},
        {"klics_ch_float",NULL,0,18,FW_float,(String)&flt_inputs[3]},
        {"klics_ch_scroll",NULL,4,18,FW_scroll,(String)&flt_inputs[3]},
        {"klics_di_float",NULL,0,20,FW_float,(String)&flt_inputs[4]},
        {"klics_di_scroll",NULL,4,20,FW_scroll,(String)&flt_inputs[4]},
        {"klics_oct_form",NULL,0,22,FW_form,NULL},
        {"klics_vid_form",NULL,0,24,FW_form,NULL},
}, vid_items[]={
        {"klics_ic_lab","Image Comp:",0,0,FW_label,NULL},
        {"klics_ic",NULL,1,0,FW_yn,(String)&ctrl->stillvid},
        {"klics_tg_float",NULL,0,1,FW_float,(String)&flt_inputs[5]},
        {"klics_tg_scroll",NULL,1,1,FW_scroll,(String)&flt_inputs[5]},
        {"klics_px_int",NULL,0,3,FW_integer,(String)&num_inputs[0]},
        {"klics_px_down",NULL,1,3,FW_down,(String)&num_inputs[0]},
        {"klics_px_up",NULL,6,3,FW_up,(String)&num_inputs[0]},
        {"klics_auto_lab","Auto Quant:",0,5,FW_label,NULL},
        {"klics_auto",NULL,1,5,FW_yn,(String)&ctrl->auto_q},
        {"klics_buf_lab","Buffer:",0,8,FW_label,NULL},
        {"klics_buf",NULL,1,8,FW_yn,(String)&ctrl->buf_switch},
        {"klics_buf_btn","None",11,8,FW_button,"klics_cng_filt"},
        {"klics_hs_int",NULL,0,10,FW_integer,(String)&num_inputs[1]},
        {"klics_hs_down",NULL,1,10,FW_down,(String)&num_inputs[1]},
        {"klics_hs_up",NULL,14,10,FW_up,(String)&num_inputs[1]},
}, oct_items[2*space];
```

```
MenuItem        dec_menu[]={
        {"klics_dec_max",smeBSBObjectClass,"Maximum",NULL},
        {"klics_dec_abs",smeBSBObjectClass,"SigmaAbs",NULL},
        {"klics_dec_sqr",smeBSBObjectClass,"SigmaSqr",NULL},
}, filt_menu[]={
        {"klics_filt_none",smeBSBObjectClass,"None",NULL},
        {"klics_filt_exp",smeBSBObjectClass,"Exp",NULL},
};
XtCallbackRec           callbacks[]={
        {Destroy,(caddr_t)shell},
        {NULL,NULL},
        {CompressCtrl,(caddr_t)ctrl},
        {Destroy,(caddr_t)shell},
        {NULL,NULL},
        {ChangeYN,(caddr_t)&ctrl->stats_switch}, {NULL,NULL},
        {ChangeYN,(caddr_t)&ctrl->bin_switch}, {NULL,NULL},
        {FloatIncDec,(caddr_t)&flt_inputs[0]}, {NULL,NULL},
        {FloatIncDec,(caddr_t)&flt_inputs[1]}, {NULL,NULL},
        {FloatIncDec,(caddr_t)&flt_inputs[2]}, {NULL,NULL},
        {FloatIncDec,(caddr_t)&flt_inputs[3]}, {NULL,NULL},
        {FloatIncDec,(caddr_t)&flt_inputs[4]}, {NULL,NULL},
}, vid_call[]={
        {ChangeYN,(caddr_t)&ctrl->stillvid}, {NULL,NULL},
        {FloatIncDec,(caddr_t)&flt_inputs[5]}, {NULL,NULL},
        {NumIncDec,(caddr_t)&num_inputs[0]}, {NULL,NULL},
        {NumIncDec,(caddr_t)&num_inputs[0]}, {NULL,NULL},
        {ChangeYN,(caddr_t)&ctrl->auto_q}, {NULL,NULL},
        {ChangeYN,(caddr_t)&ctrl->buf_switch}, {NULL,NULL},
        {NumIncDec,(caddr_t)&num_inputs[1]}, {NULL,NULL},
        {NumIncDec,(caddr_t)&num_inputs[1]}, {NULL,NULL},
}, dec_call[]={
        {SimpleMenu,(caddr_t)&ctrl->decide}, {NULL,NULL},
```

```
        {SimpleMenu,(caddr_t)&ctrl->decide}, {NULL,NULL},
        {SimpleMenu,(caddr_t)&ctrl->decide}, {NULL,NULL},
}, filt_call[]={
        {SimpleMenu,(caddr_t)&ctrl->filter}, {NULL,NULL},
        {SimpleMenu,(caddr_t)&ctrl->filter}, {NULL,NULL},
}, oct_call[2*space];
XFontStruct    *font;
Arg     args[1];

msg->rows=1; msg->cols=NAME_LEN;
msg_stats->rows=1; msg_stats->cols=NAME_LEN;
msg_bin->rows=1; msg_bin->cols=NAME_LEN;
ctrl->src=(Video)closure;

flt_inputs[0].format="Quant: %4.1f";
flt_inputs[0].max=10;
flt_inputs[0].min=0;
flt_inputs[0].value= &ctrl->quant_const;

flt_inputs[1].format="Thresh: %4.1f";
flt_inputs[1].max=10;
flt_inputs[1].min=0;
flt_inputs[1].value= &ctrl->thresh_const;

flt_inputs[2].format="Comp: %4.1f";
flt_inputs[2].max=10;
flt_inputs[2].min=0;
flt_inputs[2].value= &ctrl->cmp_const;

flt_inputs[3].format="Chrome: %4.1f";
flt_inputs[3].max=5;
flt_inputs[3].min=1;
```

```
flt_inputs[3].value= &ctrl->chrome_factor;

flt_inputs[4].format="Diag: %4.1f";
flt_inputs[4].max=2.0;
flt_inputs[4].min=1.0;
flt_inputs[4].value= &ctrl->diag_factor;

flt_inputs[5].format="Target: %4.1f";
flt_inputs[5].max=30.0;
flt_inputs[5].min=10.0;
flt_inputs[5].value= &ctrl->fps;

num_inputs[0].format="px64k: %1d";
num_inputs[0].max=8;
num_inputs[0].min=1;
num_inputs[0].value= &ctrl->bitrate;

num_inputs[1].format="History: %1d";
num_inputs[1].max=8;
num_inputs[1].min=1;
num_inputs[1].value= &ctrl->feedback;

for(i=0;i<space;i++) {
        String  format=(char *)MALLOC(20);

        if (i==0) sprintf(format,"Octave LPF: %%4.2f");
        else sprintf(format,"Octave %3d: %%4.2f",space-i-1);
        oct_inputs[i].format=format;
        oct_inputs[i].max=1.0;
        oct_inputs[i].min=0.0;
        oct_inputs[i].value= &ctrl->base_factors[space-i-1];
        oct_items[2*i].name="klics_oct_float";
```

```
            oct_items[2*i].contents=NULL;
            oct_items[2*i].fromHoriz=0;
            oct_items[2*i].fromVert=i==0?0:2*i-1;
            oct_items[2*i].type=FW_float;
            oct_items[2*i].hook=(String)&oct_inputs[i];
            oct_items[2*i+1].name="klics_oct_scroll";
            oct_items[2*i+1].contents=NULL;
            oct_items[2*i+1].fromHoriz=1;
            oct_items[2*i+1].fromVert=i==0?0:2*i-1;
            oct_items[2*i+1].type=FW_scroll;
            oct_items[2*i+1].hook=(String)&oct_inputs[i];
            oct_call[2*i].callback=FloatIncDec;
            oct_call[2*i].closure=(String)&oct_inputs[i];
            oct_call[2*i+1].callback=NULL;
            oct_call[2*i+1].closure=NULL;
        }
        FillForm(form,COMP_ICONS-(video->size[2]>1?0:1),items,widgets,callbacks);
        FillForm(widgets[23],2*space,oct_items,oct_widgets,oct_call);
        FillMenu(dec_shell,THREE,dec_menu,dec_widgets,dec_call);
        font=FindFont(widgets[12]);

    XtSetArg(args[0],XtNwidth,2+TextWidth(0,"Maximum\nSigmaAbs\nSigmaSqr",font));
        XtSetValues(widgets[12],args,ONE);
        if (video->size[2]>1) {
            FillForm(widgets[24],VID_ICONS,vid_items,vid_widgets,vid_call);
            FillMenu(filt_shell,TWO,filt_menu,filt_widgets,filt_call);
            font=FindFont(vid_widgets[11]);
            XtSetArg(args[0],XtNwidth,2+TextWidth(0,"None\nExp",font));
            XtSetValues(vid_widgets[11],args,ONE);
        }
        XtPopup(shell,XtGrabExclusive);
    }
```

source/KlicsSA.c

```
/*
        Full still/video Knowles-Lewis Image Compression System utilising HVS
properties
        and delta-tree coding

        Stand-Alone version uses fixed image format and static data structures
*/

#include        "KlicsSA.h"
#include        <math.h>

extern void     Convolve();

/* useful X definitions */
typedef         char    Boolean;
#define True    1
#define False   0
#define         String  char*

/* token modes (empty) */
#define         EMPTY           0
#define         CHANNEL_EMPTY           1
#define         OCTAVE_EMPTY    2
#define         LPF_EMPTY       3
#define FULL                    4

/*      Function Name:          AccessSA
 *      Description:    Find index address from co-ordinates
 *      Arguments:      x, y - (x,y) co-ordinates
```

```
*                           oct, sub, channel - octave, sub-band and channel co-ordinates
*     Returns: index into data[channel][][index]
*/

int   AccessSA(x,y,oct,sub,channel)

int   x, y, oct, sub, channel;

{

return((((x<<1)+(sub>>1)+(SA_WIDTH>>(channel==0?0:1))*((y<<1)+(1&sub)
))<<oct);
}

/*    Function Name:      DecideSA
 *    Description:  Calculate value representing the difference between new and old
blocks
 *    Arguments:    new, old - blocks to compare
 *    Returns:      difference value
 */

int   DecideSA(new,old)

Block new, old;

{
      int   X, Y, sigma=0;

      for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
sigma+=abs(new[X][Y]-old[X][Y]);
      return(sigma);
}
```

```
/*      Function Name:     DecideDoubleSA
 *      Description:  Calculates normal w.r.t differencing algorithm
 *      Arguments:    norm - normal value
 *      Returns:      new normal value
 */

double        DecideDoubleSA(norm)

double        norm;

{
        return(4.0*norm);
}

Boolean       DecisionSA(new,old,norm)

Block  new, old;
double        norm;

{
        return((double)DecideSA(new,old)<=DecideDoubleSA(norm));
}

/*      Function Name:     HuffmanSA
 *      Description:  Calculates the number of bits for the Huffman code representing
level
 *      Arguments:    level - level to be encoded
 *      Returns:      number of bits in codeword
 */

int     HuffmanSA(level)
```

```
int     level;

{
        return(level==0?2:(abs(level)<3?3:1+abs(level)));
}

/*      Function Name:      HuffCodeSA
 *      Description:   Generates Huffman code representing level
 *      Arguments:     level - level to be encoded
 *      Returns:       coded bits in char's
 */

unsigned char *HuffCodeSA(level)

int     level;

{
        unsigned char *bytes=(unsigned char *)MALLOC((7+Huffman(level))/8);

        bytes[0]=(abs(level)<3?abs(level):3)|(level<0?4:0);
        if (abs(level)>2) {
                int     index=(7+Huffman(level))/8-1;

                bytes[index]=bytes[index]|(1<<(Huffman(level)-1)%8);
        }
        return(bytes);
}

unsigned char *CodeIntSA(number,bits)

int     number, bits;
```

```
{
        int     len=(7+bits)/8;
        unsigned char *bytes=(unsigned char *)MALLOC(len);
        int     byte;

        for(byte=0;byte<len;byte++) {
                bytes[byte]=0xff&number;
                number=number>>8;
        }
        return(bytes);
}

int     ReadIntSA(bits,bfp)

int     bits;
Bits    bfp;

{
        int     len=(7+bits)/8;
        unsigned char bytes[len];
        int     byte, number=0;

        bread(bytes,bits,bfp);
        for(byte=0;byte<len;byte++)
                number=number|((int)bytes[byte]<<byte*8);
        number=(number<<sizeof(int)*8-bits)>>sizeof(int)*8-bits;
        return(number);
}

/*      Function Name:      HuffReadSA
 *      Description:   Read Huffman encoded number from binary file
 *      Arguments:     bfp - binary file pointer
```

```
 *      Returns:        decoded level
 */

int     HuffReadSA(bfp)

Bits    bfp;

{
        int     value;
        unsigned char           byte;
        Boolean         negative=False;

        bread(&byte,2,bfp);
        value=(int)byte;
        if (byte=='\0') return(0);
        else {
                bread(&byte,1,bfp);
                negative=(byte!='\0');
        }
        if (value<3) return(negif(negative,value));
        for(byte='\0';byte=='\0';value++) bread(&byte,1,bfp);
        return(negif(negative,value-1));
}

/*      Function Name:          QuantizeSA
 *      Description:    RM8 style quantizer
 *      Arguments:      data - unquantised number
 *                              q - quantizing divisor
 *                              level - quantised to level
 *      Returns:        quantized data & level
 */
```

```
int     QuantizeSA(data,q,level)

int     data, q, *level;

{
        int     mag_level=abs(data)/q;

        *level=negif(data<0,mag_level);
        return(negif(data<0,mag_level*q+(mag_level!=0?(q-1)>>1:0)));
}

/*      Function Name:      ProposedSA
 *      Description:    Calculates proposed block values
 *      Arguments:      pro - proposed block
 *                              lev - proposed block quantized levels
 *                              old, new - old and new block values
 *                              norms - HVS normals
 *      Returns:        new==0, proposed values (pro) and levels (lev)
 */

Boolean     ProposedSA(pro,lev,old,new,norms)

Block  pro, lev, old, new;
double      norms[3];

{
        Block  zero_block={{0,0},{0,0}};
        int     X, Y, step=norms[0]<1.0?1:(int)norms[0];
        Boolean     zero=DecisionSA(new,zero_block,norms[1]);

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
```

```
pro[X][Y]=zero?0:old[X][Y]+Quantize(new[X][Y]-old[X][Y],step,&(lev[X][Y]));
        return(zero);
}

/*      Function Name:      ZeroCoeffsSA
 *      Description:   Zero out video data
 *      Arguments:     data - image data
 *                          addr - addresses
 *      Returns:       zeros data[addr[][]]
 */

void    ZeroCoeffsSA(data,addr)

short   *data;
Block   addr;

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
                data[addr[X][Y]]=0;
}

/*      Function Name:      BlockZeroSA
 *      Description:   Test if all block values are zero
 *      Arguments:     block - block under test
 *      Returns:       block==0
 */

Boolean         BlockZeroSA(block)

Block   block;
```

```
{
        int      X, Y;
        Boolean        zero=True;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)
                if (block[X][Y]!=0) zero=False;
        return(zero);
}

/*      Function Name:     SendTokenSA
 *      Description:  Increments token frequency
 *      Arguments:    token - token to be transmitted
 *                         channel, sub, oct - co-ordinates
 *                         bfp - binary file pointer
 *                         empty - zero state {EMPTY | CHANNEL_EMPTY |
OCTAVE_EMPTY | LPF_EMPTY | FULL}
 *                         branch - branch of tree (0-3)
 *      Returns:      encodes token
 */

void    SendTokenSA(token,channel,sub,oct,bfp,empty,branch)

int     token, channel, sub, oct, *empty, branch;
Bits    bfp;

{
        int      full=FULL, i;
        String
token_name[TOKENS]={"ZERO_STILL","NON_ZERO_STILL","BLOCK_SAME","ZE
RO_VID","BLOCK_CHANGE",

"LOCAL_ZERO","LOCAL_NON_ZERO","CHANNEL_ZERO","CHANNEL_NON_ZE
```

```
RO","OCT_ZERO","OCT_NON_ZERO",

"LPF_ZERO","LPF_NON_ZERO","LPF_LOC_ZERO","LPF_LOC_NON_ZERO"};

        switch(*empty) {
        case EMPTY:
                if (token!=ZERO_STILL && token!=BLOCK_SAME) {

SendTokenSA(LOCAL_NON_ZERO,channel,sub,oct,bfp,&full,branch);
                        for(i=0;i<channel;i++)
SendTokenSA(CHANNEL_ZERO,i,sub,oct,bfp,&full,branch);
                        *empty=CHANNEL_EMPTY;
                        SendTokenSA(token,channel,sub,oct,bfp,empty,branch);
                }
                break;
        case CHANNEL_EMPTY:
                if (token!=ZERO_STILL && token!=BLOCK_SAME) {

SendTokenSA(CHANNEL_NON_ZERO,channel,sub,oct,bfp,&full,branch);
                        for(i=1;i<sub;i++)
SendTokenSA(token==NON_ZERO_STILL?ZERO_STILL:BLOCK_SAME,channel,i,oc
t,bfp,&full,branch);
                        *empty=FULL;
                        SendTokenSA(token,channel,sub,oct,bfp,empty,branch);
                }
                break;
        case OCTAVE_EMPTY:
                if (token!=ZERO_STILL && token!=BLOCK_SAME) {

SendTokenSA(OCT_NON_ZERO,channel,sub,oct,bfp,&full,branch);
                        for(i=0;i<branch;i++)
SendTokenSA(token==NON_ZERO_STILL?ZERO_STILL:BLOCK_SAME,channel,sub
```

```
,oct,bfp,&full,branch);
                        *empty=FULL;
                        SendTokenSA(token,channel,sub,oct,bfp,empty,branch);
                }
                break;
        case LPF_EMPTY:
                if (token!=LPF_ZERO) {

SendTokenSA(LPF_LOC_NON_ZERO,channel,sub,oct,bfp,&full,branch);
                        for(i=0;i<channel;i++)
SendTokenSA(LPF_ZERO,i,sub,oct,bfp,&full,branch);
                        *empty=FULL;
                        SendTokenSA(token,channel,sub,oct,bfp,empty,branch);
                }
                break;
        case FULL:
                Dprintf("%s\n",token_name[token]);
                bwrite(&token_codes[token],token_bits[token],bfp);
                break;
        }
}

/*      Function Name:      ReadBlockSA
 *      Description:    Read block from video
 *      Arguments:      new, old, addr - new and old blocks and addresses
 *                              x, y, oct, sub, channel - co-ordinates of block
 *                              src, dst - frame data
 *      Returns:        block values
 */

void    ReadBlockSA(new,old,addr,x,y,oct,sub,channel,src,dst)
```

```
Block  new, old, addr;
int    x, y, oct, sub, channel;
short  *src[3], *dst[3];

{
       int      X, Y;

       for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++) {
              addr[X][Y]=AccessSA((x<<1)+X,(y<<1)+Y,oct,sub,channel);
              new[X][Y]=(int)src[channel][addr[X][Y]];
              old[X][Y]=(int)dst[channel][addr[X][Y]];
       }
}

/*     Function Name:    CalcNormalsSA
 *     Description:  Calculates HVS weighted normals
 *     Arguments:    oct, sub, channel - co-ordinates
 *                        norms - pre-initialised normals
 *     Returns:      weighted normals
 */

void   CalcNormalsSA(oct,sub,channel,norms,quant_const)

int    oct, sub, channel;
double        norms[3], quant_const;

{
       int     norm, base_oct=oct+(channel!=0?1:0)+(sub==0?1:0);

       for(norm=0;norm<3;norm++) {
              if (norm!=0) norms[norm] *= quant_const;
              norms[norm] *= base_factors[base_oct]*(sub==3?diag_factor:1.0);
```

```
            if (channel!=0) norms[norm] *= chrome_factor;
            norms[norm] *=(double)(1<<SA_PRECISION);
      }
}

/*    Function Name:    MakeDecisions2SA
 *    Description:  Decide on new compression mode from block values
 *    Arguments:    old, new, pro - block values
 *                      zero - zero flag for new block
 *                      norms - HVS normals
 *                      mode - current compression mode
 *                      decide - comparison algorithm
 *    Returns:      new compression mode
 */

int   MakeDecisions2SA(old,new,pro,lev,zero,norms,mode)

Block new, old, pro, lev;
Boolean     zero;
double      norms[3];
int   mode;

{
      Block zero_block={{0,0},{0,0}};
      int   new_mode=mode==STILL || BlockZeroSA(old)?STILL:SEND,
                  np=DecideSA(new,pro), no=DecideSA(new,old);

      if (new_mode==STILL) new_mode=np>=no || zero ||
BlockZeroSA(lev)?STOP:STILL;
      else new_mode=zero && np<no?VOID:np>=no ||
DecisionSA(new,old,norms[2]) || BlockZeroSA(lev)?STOP:SEND;
      return(new_mode);
```

```
}

/*      Function Name:      UpdateCoeffsSA
 *      Description:   Encode proposed values and write data
 *      Arguments:     pro, lev, addr - proposed block, levels and addresses
 *                          channel, oct - co-ordinates
 *                          dst - destination data
 *                          bfp - binary file pointer
 *      Returns:       alters dst[channel][addr[][]]
 */

void    UpdateCoeffsSA(pro,lev,addr,channel,oct,dst,bfp)

Block   pro, lev, addr;
int     channel, oct;
short   *dst[3];
Bits    bfp;

{
        int     X, Y;

        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++) {
                int     bits=HuffmanSA(lev[X][Y]),
                            level=abs(lev[X][Y]);
                unsigned char       *bytes=HuffCodeSA(lev[X][Y]);

                dst[channel][addr[X][Y]]=(short)pro[X][Y];
                bwrite(bytes,bits,bfp);
                XtFree(bytes);
        }
}
```

```
/*      Function Name:      SendTreeSA
 *      Description:  Encode tree blocks
 *      Arguments:    prev_mode - compression mode
 *                          x, y, oct, sub, channel - co-ordinates
 *                          empty - token mode
 *                          branch - tree branch number
 *      Returns:        active block indicator
 */

Boolean
SendTreeSA(prev_mode,x,y,oct,sub,channel,src,dst,empty,branch,quant_const,bfp)

int     prev_mode, x, y, oct, sub, channel, *empty, branch;
short   *src[3], *dst[3];
double          quant_const;
Bits    bfp;

{
        Block   addr, old, new, pro, lev;
        int     new_mode, X, Y;
        double          norms[3]={quant_const,thresh_const,cmp_const}; /* quant, thresh,
compare */
        Boolean         active=False;

        ReadBlockSA(new,old,addr,x,y,oct,sub,channel,src,dst);
        if (prev_mode!=VOID) {
                Boolean         zero;

                CalcNormalsSA(oct,sub,channel,norms,quant_const);
                zero=ProposedSA(pro,lev,old,new,norms);
                new_mode=MakeDecisions2SA(old,new,pro,lev,zero,norms,prev_mode);
                switch(new_mode) {
```

```
            case STOP:
                    SendTokenSA(prev_mode==STILL ||
BlockZeroSA(old)?ZERO_STILL:BLOCK_SAME,channel,sub,oct,bfp,empty,branch);
                    break;
            case STILL:
            case SEND:
                    active=True;
                    SendTokenSA(prev_mode==STILL ||
BlockZero(old)?NON_ZERO_STILL:BLOCK_CHANGE,channel,sub,oct,bfp,empty,bran
ch);
                    UpdateCoeffsSA(pro,lev,addr,channel,oct,dst,bfp);
                    break;
            case VOID:
                    SendTokenSA(ZERO_VID,channel,sub,oct,bfp,empty,branch);
                    ZeroCoeffsSA(dst[channel],addr);
                    break;
            }
        } else {
            if (BlockZeroSA(old)) new_mode=STOP;
            else {
                    ZeroCoeffsSA(dst[channel],addr);
                    new_mode=VOID;
            }
        }
        if (oct>0 && new_mode!=STOP) {
            int     mt=OCTAVE_EMPTY, full=FULL;

            Dprintf("x=%d, y=%d, oct=%d sub=%d mode
%d\n",x,y,oct,sub,new_mode);
            for(Y=0;Y<2;Y++) for(X=0;X<2;X++)

(void)SendTreeSA(new_mode,x*2+X,y*2+Y,oct-1,sub,channel,src,dst,&mt,X+2*Y,qua
```

```
nt_const.bfp);
            if (mt==OCTAVE_EMPTY && new_mode!=VOID)
SendTokenSA(OCT_ZERO,channel,sub,oct,bfp,&full,0);
      }
      return(active);
}

/*    Function Name:      SendLPF_SA
 *    Description:   Encode LPF sub-band
 *    Arguments:     mode - compression mode
 *    Returns:       encodes data
 */

void  SendLPF_SA(mode,src,dst,bfp,quant_const)

int   mode;
short *src[3], *dst[3];
Bits  bfp;
double      quant_const;

{
      Block new, old, pro, lev, addr;
      int   channel, channels=3, x, y, full=FULL,
                  octs_lum=3,

size[2]={SA_WIDTH>>octs_lum+1,SA_HEIGHT>>octs_lum+1};

      for(y=0;y<size[1];y++) for(x=0;x<size[0];x++) {
            int   empty=LPF_EMPTY;

      for(channel=0;channel<channels;channel++) {
            int   octs=channel!=0?2:3,
```

```
                new_mode, X, Y, step, value, bits=0;
double          norms[3]={quant_const,thresh_const,cmp_const};

CalcNormalsSA(octs-1,0,channel,norms,quant_const);
step=norms[0]<1.0?1:(int)norms[0];
for(bits=0, value=((1<<8+SA_PRECISION)-1)/step;value!=0;bits++)
        value=value>>1;
ReadBlockSA(new,old,addr,x,y,octs-1,0,channel,src,dst);

/* Proposed */
for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++)

pro[X][Y]=old[X][Y]+QuantizeSA(new[X][Y]-old[X][Y],step,&(lev[X][Y]));

/* MakeDecisions */
new_mode=mode==STILL?STILL:DecisionSA(new,old,norms[2]) ||
BlockZeroSA(lev)?STOP:SEND;

switch(new_mode) {
case SEND:
        SendTokenSA(LPF_NON_ZERO,channel,0,octs,bfp,&empty,0);
        UpdateCoeffsSA(pro,lev,addr,channel,octs,dst,bfp);
break;
case STILL:
        for(X=0;X<BLOCK;X++) for(Y=0;Y<BLOCK;Y++) {
                unsigned char *bytes=CodeIntSA(lev[X][Y],bits);

                dst[channel][addr[X][Y]]=(short)pro[X][Y];
                bwrite(bytes,bits,bfp);
                XtFree(bytes);
        }
        break;
```

```
            case STOP:
                    SendTokenSA(LPF_ZERO,channel,0,octs,bfp,&empty,0);
                    break;
            }
        }
        if (mode!=STILL && empty==LPF_EMPTY)
SendTokenSA(LPF_LOC_ZERO,channel,0,octs_lum,bfp,&full,0);
        }
}

/*      Function Name:      CompressFrameSA
 *      Description:  Compress a Frame
 *      Arguments:    mode - compression mode STILL or SEND
 *                           src, dst - source and destination data
 *                           bfp - binary file pointer for result
 *                           quant_const - quantization parameter
 */

void    CompressFrameSA(mode,src,dst,bfp,quant_const)

int     mode;
short   *src[3], *dst[3];
Bits    bfp;
double          quant_const;

{
        int     sub, channel, x, y, i,
                        octs_lum=3,

size[2]={SA_WIDTH>>1+octs_lum,SA_HEIGHT>>1+octs_lum};

        for(channel=0;channel<3;channel++) {
```

```
            int
frame_size[2]={SA_WIDTH>>(channel==0?0:1),SA_HEIGHT>>(channel==0?0:1
)},
                              frame_area=frame_size[0]*frame_size[1];

            for(i=0;i<frame_area;i++)
src[channel][i]=src[channel][i]<<SA_PRECISION;
            Convolve(src[channel],False,frame_size,0,channel==0?3:2);
        }
        bwrite((char *)&quant_const,sizeof(double)*8,bfp);
        SendLPF_SA(mode,src,dst,bfp,quant_const);
        for(y=0;y<size[1];y++) for(x=0;x<size[0];x++) {
            int     empty=EMPTY, full=FULL;

            for(channel=0;channel<3;channel++) {
                int     octs=channel!=0?2:3;

                for(sub=1;sub<4;sub++)
(void)SendTreeSA(mode,x,y,octs-1,sub,channel,src,dst,&empty,0,quant_const,bfp);
                switch(empty) {
                case FULL:
                    empty=CHANNEL_EMPTY;
                    break;
                case CHANNEL_EMPTY:
SendTokenSA(CHANNEL_ZERO,channel,sub,octs-1,bfp,&full,0);
                    break;
                }
            }
            if (empty==EMPTY)
SendTokenSA(LOCAL_ZERO,channel,sub,octs_lum-1,bfp,&full,0);
        }
}
```

source/KlicsTestSA.c

```
#include        "xwave.h"
#include        "KlicsSA.h"

extern void   CompressFrameSA();

typedef         struct {
        Video src;
        char  bin_name[STRLEN];
        Boolean         stillvid;
        double          quant_const;
} KlicsCtrlRec, *KlicsCtrl;

/*      Function Name:      KlicsCtrlSA
 *      Description:  Test harness for KlicsSA in xwave
 *      Arguments:          w - Xaw widget
 *                               closure - compression control record
 *                               call_data - NULL
 *      Returns:      send data to binary file
 */

void    KlicsCtrlSA(w,closure,call_data)

Widget        w;
caddr_t       closure, call_data;

{
        KlicsCtrl      ctrl=(KlicsCtrl)closure;
        int     sizeY=SA_WIDTH*SA_HEIGHT,
```

```
                sizeUV=SA_WIDTH*SA_HEIGHT/4, i, z;
        short   *dst[3]={
                (short *)MALLOC(sizeof(short)*sizeY),
                (short *)MALLOC(sizeof(short)*sizeUV),
                (short *)MALLOC(sizeof(short)*sizeUV),
        }, *src[3]={
                (short *)MALLOC(sizeof(short)*sizeY),
                (short *)MALLOC(sizeof(short)*sizeUV),
                (short *)MALLOC(sizeof(short)*sizeUV),
        };

        char    file_name[STRLEN];
        Bits    bfp;
        Boolean         true=True, false=False;

        for(i=0;i<sizeY;i++) dst[0][i]=0;
        for(i=0;i<sizeUV;i++) { dst[1][i]=0; dst[2][i]=0; }


sprintf(file_name,"%s%s/%s%s\0",global->home,KLICS_SA_DIR,ctrl->bin_name,KLI
CS_SA_EXT);
        bfp=bopen(file_name,"w");
        bwrite(&ctrl->stillvid,1,bfp);
        bwrite(&ctrl->src->size[2],sizeof(int)*8,bfp);
        for(z=0;z<ctrl->src->size[2];z++) {
                GetFrame(ctrl->src,z);
                for(i=0;i<sizeY;i++) src[0][i]=ctrl->src->data[0][z][i];
                for(i=0;i<sizeUV;i++) {
                        src[1][i]=ctrl->src->data[1][z][i];
                        src[2][i]=ctrl->src->data[2][z][i];
                }
                CompressFrameSA(z==0 ||
```

```
ctrl->stillvid?STILL:SEND,src,dst,bfp,ctrl->quant_const);
                FreeFrame(ctrl->src,z);
        }
        bflush(bfp);
        bclose(bfp);
        XtFree(dst[0]);
        XtFree(dst[1]);
        XtFree(dst[2]);
        XtFree(src[0]);
        XtFree(src[1]);
        XtFree(src[2]);
}

KlicsCtrl       InitKlicsCtrl(name)

String  name;

{
        KlicsCtrl       ctrl=(KlicsCtrl)MALLOC(sizeof(KlicsCtrlRec));

        ctrl->stillvid=True;
        ctrl->quant_const=8.0;
        strcpy(ctrl->bin_name,name);
        return(ctrl);
}

#define         KLICS_SA_ICONS  8
#define KLICS_SA_VID_ICONS      2

void    KlicsSA(w,closure,call_data)

Widget          w;
```

```
caddr_t         closure, call_data;

{
        Video  video=(Video)closure;
        KlicsCtrl       ctrl=InitKlicsCtrl(video->name);
        FloatInput      flt_inputs=(FloatInput)MALLOC(sizeof(FloatInputRec));
        Message         msg_bin=NewMessage(ctrl->bin_name,NAME_LEN);
        XtCallbackRec           destroy_call[]={
                {Free,(caddr_t)ctrl},
                {Free,(caddr_t)flt_inputs},
                {CloseMessage,(caddr_t)msg_bin},
                {NULL,NULL},
        };
        Widget          parent=FindWidget("frm_compress",XtParent(w)),

shell=ShellWidget("klicsSA",parent,SW_below,NULL,destroy_call),
                        form=FormatWidget("klicsSA_form",shell),
                        widgets[KLICS_SA_ICONS],
vid_widgets[KLICS_SA_VID_ICONS];
        FormItem        items[]={
                {"klicsSA_cancel","cancel",0,0,FW_icon,NULL},
                {"klicsSA_confirm","confirm",1,0,FW_icon,NULL},
                {"klicsSA_title","Run Klics SA",2,0,FW_label,NULL},
                {"klicsSA_bin_lab","KLICS File:",0,3,FW_label,NULL},
                {"klicsSA_bin_name",NULL,4,3,FW_text,(String)msg_bin},

                {"klicsSA_qn_float",NULL,0,5,FW_float,(String)&flt_inputs[0]},
                {"klicsSA_qn_scroll",NULL,6,5,FW_scroll,(String)&flt_inputs[0]},
                {"klicsSA_vid_form",NULL,0,7,FW_form,NULL},
        }, vid_items[]={
                {"klicsSA_ic_lab","Image Comp:",0,0,FW_label,NULL},
                {"klicsSA_ic",NULL,1,0,FW_yn,(String)&ctrl->stillvid},
        };
```

```
	XtCallbackRec		callbacks[]={
		{Destroy,(caddr_t)shell},
		{NULL,NULL},
		{KlicsCtrlSA,(caddr_t)ctrl},
		{Destroy,(caddr_t)shell},
		{NULL,NULL},
		{FloatIncDec,(caddr_t)&flt_inputs[0]}, {NULL,NULL},
	}, vid_call[]={
		{ChangeYN,(caddr_t)&ctrl->stillvid}, {NULL,NULL},
	};

	ctrl->src=video;
	msg_bin->rows=1; msg_bin->cols=NAME_LEN;

	flt_inputs[0].format="Quant: %4.1f";
	flt_inputs[0].max=10;
	flt_inputs[0].min=0;
	flt_inputs[0].value= &ctrl->quant_const;


FillForm(form,KLICS_SA_ICONS-(video->size[2]>1?0:1),items,widgets,callbacks);
	if (video->size[2]>1)

FillForm(widgets[7],KLICS_SA_VID_ICONS,vid_items,vid_widgets,vid_call);
	XtPopup(shell,XtGrabExclusive);
}
```

source/Malloc.c

```
/*
        Memory allocation routine
*/

#include        <stdio.h>

char    *MALLOC(size)

int     size;

{
        char *ptr=(char *)calloc(1,size);

        if (ptr==NULL) Eprintf("Unable to allocate %d bytes of memory\n",size);
        return(ptr);
}
```

source/Menu.c

```
        /*
         *      Pull-Right Menu functions
         */

#include        <stdio.h>
#include        <X11/IntrinsicP.h>
#include        <X11/StringDefs.h>

#include        <X11/Xaw/XawInit.h>
#include        <X11/Xaw/SimpleMenP.h>
#include        <X11/Xaw/CommandP.h>

static  void    prPopupMenu();
static  void    NotifyImage();
static  void    PrLeave();

void    InitActions(app_con)

XtAppContext            app_con;

{
        static  XtActionsRec            actions[]={
                {"prPopupMenu",prPopupMenu},
                {"notifyImage",NotifyImage},
                {"prLeave",PrLeave},
        };

        XtAppAddActions(app_con,actions,XtNumber(actions));
```

```
}

static void prPopupMenu(w,event,params,num_params)

Widget w;
XEvent * event;
String * params;
Cardinal * num_params;

{
  Widget menu, temp;
  Arg arglist[2];
  Cardinal num_args;
  int menu_x, menu_y, menu_width, menu_height, button_width, button_height;
  Position button_x, button_y;

  if (*num_params!=1) {
        char error_buf[BUFSIZ];
        sprintf(error_buf, "prPopupMenu: %s.","Illegal number of translation
arguments");
        XtAppWarning(XtWidgetToApplicationContext(w), error_buf);
        return;
  }
  temp = w;
  while(temp != NULL) {
    menu = XtNameToWidget(temp, params[0]);
    if (menu == NULL)
      temp = XtParent(temp);
    else
      break;
  }
```

```
if (menu == NULL) {
  char error_buf[BUFSIZ];
  sprintf(error_buf, "prPopupMenu: %s %s.",
          "Could not find menu widget named", params[0]);
  XtAppWarning(XtWidgetToApplicationContext(w), error_buf);
  return;
}
if (!XtIsRealized(menu))
  XtRealizeWidget(menu);

menu_width = menu->core.width + 2 * menu->core.border_width;
button_width = w->core.width + 2 * w->core.border_width;
button_height = w->core.height + 2 * w->core.border_width;

menu_height = menu->core.height + 2 * menu->core.border_width;

XtTranslateCoords(w, 0, 0, &button_x, &button_y);
menu_x = button_x;
menu_y = button_y + button_height;

if (menu_x < 0)
  menu_x = 0;
else {
  int scr_width = WidthOfScreen(XtScreen(menu));
  if (menu_x + menu_width > scr_width)
    menu_x = scr_width - menu_width;
}

if (menu_y < 0)
  menu_y = 0;
else {
  int scr_height = HeightOfScreen(XtScreen(menu));
```

```
  if (menu_y + menu_height > scr_height)
    menu_y = scr_height - menu_height;
 }

 num_args = 0;
 XtSetArg(arglist[num_args], XtNx, menu_x); num_args++;
 XtSetArg(arglist[num_args], XtNy, menu_y); num_args++;
 XtSetValues(menu, arglist, num_args);

 XtPopupSpringLoaded(menu);
}
/*
static void
prRealize(w, mask, attrs)
Widget w;
Mask *mask;
XSetWindowAttributes *attrs;
{
 (*superclass->core_class.realize) (w, mask, attrs);
*/
 /* We have a window now. Register a grab. */
/*
 XGrabButton( XtDisplay(w), AnyButton, AnyModifier, XtWindow(w),
           TRUE, ButtonPressMask|ButtonReleaseMask,
           GrabModeAsync, GrabModeAsync, None, None );
}
*/

static  void  NotifyImage(w,event,params,num_params)

Widget     w;
XEvent     *event;
```

```
String *params;
Cardinal        *num_params;
{
        CommandWidget     cbw=(CommandWidget)w;

        if (cbw->command.set) XtCallCallbackList(w,cbw->command.callbacks,event);
}

static  void    PrLeave(w,event,params,num_params)

Widget          w;
XEvent          *event;
String *params;
Cardinal        *num_params;
{
        SimpleMenuWidget   smw=(SimpleMenuWidget)w;

        Dprintf("PrLeave\n");
}
```

source/Message.c

```
/*
 *      Message I/O Utility Routines
 */

#include        "../include/xwave.h"
#include        <varargs.h>

#define         MESS_ICONS      3

void    TextSize(msg)

Message         msg;

{
        int     i=-1, max_len=0;
        char    *text=msg->info.ptr;

        msg->rows=0;
        msg->cols=0;
        do {
                i++;
                if (text[i]=='\n' || text[i]=='\0') {
                        if (msg->cols>max_len) max_len=msg->cols;
                        msg->cols=0;
                        msg->rows++;
                } else msg->cols++;
        } while (text[i]!='\0');
        if (i>0) if (text[i-1]=='\n') msg->rows--;
```

```
	msg->cols=max_len;
}

Message	NewMessage(text,size)

char	*text;
int	size;

{
	Message	msg=(Message)MALLOC(sizeof(MessageRec));

	msg->shell=NULL;
	msg->widget=NULL;
	msg->info.firstPos=0;
	if (!(msg->own_text=text==NULL)) msg->info.ptr=text;
	else {
		msg->info.ptr=(char *)MALLOC(size+1);
		msg->info.ptr[0]='\0';
	}
	msg->info.format=FMT8BIT;
	msg->info.length=0;
	msg->rows=0;
	msg->cols=0;
	msg->size=size;
	msg->edit=XawtextEdit;
	return(msg);
}

void	CloseMessage(w,closure,call_data)

Widget	w;
caddr_t	closure, call_data;
```

```
{
        Message         msg=(Message)closure;

        Destroy(w,(caddr_t)msg->shell.NULL);
        if (msg->own_text) XtFree(msg->info.ptr);
        XtFree(msg);
}

void    MessageWindow(parent,msg,title,close,call)

Widget          parent;
Message         msg;
char    *title;
Boolean         close;
XtCallbackRec           call[];

{
        Widget          form, widgets[MESS_ICONS]={NULL,NULL,NULL};
        FormItem        items[]={
                {"msg_cancel","cancel",0,0,FW_icon,NULL},
                {"msg_label",title,1,0,FW_label,NULL},
                {"msg_msg",NULL,0,2,FW_text,(String)msg},
        };

        msg->edit=XawtextRead;

msg->shell=ShellWidget("msg",parent,parent==global->toplevel?SW_top:SW_below,
NULL,NULL);
        form=FormatWidget("msg_form",msg->shell);

FillForm(form,MESS_ICONS-(close?0:1),&items[close?0:1],&widgets[close?0:1],call);
        XtPopup(msg->shell,XtGrabNone);
```

```
    Mflush(msg);
}

void    Mflush(msg)

Message     msg;

{
    if (global->batch==NULL && msg->widget!=NULL) {
        Display     *dpy=XtDisplay(global->toplevel);
        int     i, lines=0;
        Arg     args[1];

        for(i=msg->info.length-1;lines<msg->rows && i>=0;i--)
            if (msg->info.ptr[i]=='\n' && i!=msg->info.length-1) lines++;
        i++;
        if (msg->info.ptr[i]=='\n') i++;
        strcpy(msg->info.ptr,&msg->info.ptr[i]);
        msg->info.length-=i;
        XtSetArg(args[0],XtNstring,msg->info.ptr);
        XSynchronize(dpy,True);
        XtSetValues(msg->widget,args,ONE);
        XSynchronize(dpy,False);
    }
}

void    mprintf(msg,ap)

Message     msg;
va_list     ap;

{
```

```
	char	*format;

	format=va_arg(ap,char *);
	if (global->batch!=NULL) vprintf(format,ap);
	else {
		char	text[STRLEN];
		int	i;

		vsprintf(text,format,ap);
		i=strlen(text)+msg->info.length-msg->size;
		if (i>0) {
			strcpy(msg->info.ptr,&msg->info.ptr[i]);
			msg->info.length-=i;
		}
		strcat(msg->info.ptr,text);
		msg->info.length+=strlen(text);
	}
}

void	Dprintf(va_alist)

va_dcl

{
	va_list		ap;

	if (global->debug) {
		char	*format;

		va_start(ap);
		format=va_arg(ap,char *);
		vprintf(format,ap);
```

```
            va_end(ap);
        }
}

void   Mprintf(va_alist)

va_dcl

{
        va_list         ap;
        Message         msg;

        va_start(ap);
        msg=va_arg(ap,Message);
        mprintf(msg,ap);
        va_end(ap);
}

void   Eprintf(va_alist)

va_dcl

{
        va_list         ap;
        Message         msg;
        int     rows, cols;

        va_start(ap);
        msg=NewMessage(NULL,STRLEN);
        mprintf(msg,ap);
        if (global->batch==NULL) {
                XtCallbackRec           callbacks[]={
```

```
            {CloseMessage,(caddr_t)msg},
            {NULL,NULL},
        };

        TextSize(msg);
        MessageWindow(global->toplevel,msg,"Xwave Error",True,callbacks);
    }
    va_end(ap);
}
```

source/NameButton.c

```
/*
 *      Supply MenuButton widget id to PullRightMenu button resource
 */

#include        "../include/xwave.h"

void    NameButton(w, event, params, num_params)

Widget          w;
XEvent          *event;
String  *params;
Cardinal        *num_params;

{
        MenuButtonWidget    mbw=(MenuButtonWidget) w;
        Widget          menu;
        Arg     args[1];
        String  name;
        XtSetArg(args[0],XtNmenuName,&name);
        XtGetValues(w,args,ONE);
        Dprintf("NameButton: looking for PRM %s\n",name);
        menu=FindWidget(name,w);
        if (menu != NULL) {
                Dprintf("NameButton: setting Menu Button\n");
                XtSetArg(args[0],XtNbutton,w);
                XtSetValues(menu,args,ONE);
        }
}
```

source/Palette.c

```
/*
 *      Palette re-mapping
 */

#include        "../include/xwave.h"

/*      Function Name:      ReMap
 *      Description:   Re-maps a pixel value to a new value via a mapping
 *      Arguments:     pixel - pixel value (0..max-1)
 *                            max - range of pixel values
 *                            map - palette to recode with
 *      Returns:        remapped pixel value
 */

int     ReMap(pixel,max,palette)

int     pixel, max;
Palette         palette;

{
        Map     map=palette->mappings;
        int     value=pixel;
        Boolean         inrange=False;

        while(map!=NULL && !inrange) {
                if (pixel>=map->start && pixel<=map->finish) {
                        inrange=True;
                        value=map->m*pixel+map->c;
```

```
        }
        map=map->next;
    }
    return(value<0?0:value>=max?max-1:value);
}

/*  Function Name:  FindPalette
 *  Description:  Find a palette from a list given the index
 *  Arguments:  palette - the palette list
 *                  index - the index number
 *  Returns:    the palette corresponding to the index
 */

Palette     FindPalette(palette,index)

Palette     palette;
int     index;

{
    while(index>0 && palette->next!=NULL) {
        index--;
        palette=palette->next;
    }
    return(palette);
}

/*  Function Name:  ReOrderPalettes
 *  Description:  Reverse the order of the palette list
 *  Arguments:  start, finish - the start and finish of the re-ordered list
 *  Returns: the palette list in the reverse order
 */
```

```
Palette ReOrderPalettes(start,finish)

Palette start, finish;

{
        Palette list=finish->next;

        if (list!=NULL) {
                finish->next=list->next;
                list->next=start;
                start=ReOrderPalettes(list,finish);
        }
        return(start);
}
```

source/Parse.c

```
/*
 *      Parser for xwave input files: .elo
 */

#include        "../include/xwave.h"
#include        "../include/Gram.h"

void    Parse(path,file,ext)

String path, file, ext;

{
        char    file_name[STRLEN];

        sprintf(file_name,"%s%s/%s%s\0",global->home,path,file,ext);
        Dprintf("Parse: parsing file %s\n",file_name);
        if (NULL==(global->parse_fp=fopen(file_name,"r")))
                Eprintf("Parse: failed to open input file %s\n",file_name);
        else {
                sprintf(file_name,"%s%s\0",file,ext);
                global->parse_file=file_name;
                global->parse_token=ext;
                yyparse();
                fclose(global->parse_fp);
                Dprintf("Parse: finished with %s\n",file_name);
        }
}
```

```
void    ParseCtrl(w,closure,call_data)

Widget        w;
caddr_t       closure, call_data;

{
      Parse(".",((XawListReturnStruct *)call_data)->string,(String)closure);
}

int     ParseInput(fp)

FILE  *fp;

{
      int     num;

      if (global->parse_token!=NULL)
            if (global->parse_token[0]=='\0') {
                  num=(int)'\n';
                  global->parse_token=NULL;
            } else {
                  num=(int)global->parse_token[0];
                  global->parse_token++;
            }
      else if (EOF==(num=getc(global->parse_fp))) num=NULL;
      return(num);
}
```

source/Pop2.c

```
/*
	Global callbacks for popping popups and allsorted utilities
*/

#include	"../include/xwave.h"

void	Destroy(w,closure,call_data)

Widget		w;
caddr_t		closure, call_data;

{
	Widget		widget=(Widget)closure;

	if (widget!=NULL) XtDestroyWidget(widget);
}

void	Quit(w,closure,call_data)

Widget		w;
caddr_t		closure, call_data;

{
	XtDestroyApplicationContext(global->app_con);
	exit();
}

void	Free(w,closure,call_data)
```

```
Widget      w;
caddr_t     closure, call_data;

{
    if (closure!=NULL) XtFree(closure);
}

Widget      FindWidget(name,current)

String  name;
Widget      current;

{
    Widget      target=NULL;

    while(current!=NULL) {
        target=XtNameToWidget(current,name);
        if (target==NULL) current=XtParent(current);
        else break;
    }
    if (target==NULL) {
        Eprintf("Cant find widget: %s\n",name);
        target=global->toplevel;
    }
    return(target);
}

#define     NA_ICONS   2

void    NA(w,closure,call_data)

Widget      w;
```

```
caddr_t      closure, call_data;

{
        Widget
shell=ShellWidget("na_shell",(Widget)closure,SW_below,NULL,NULL),
                form=FormatWidget("na_form",shell), widgets[NA_ICONS];
        FormItem    items[]={
                {"na_confirm","confirm",0,0,FW_icon,NULL},
                {"na_label","This function is not available",0,1,FW_label,NULL},
        };
        XtCallbackRec       callbacks[]={
                {Destroy,(caddr_t)shell}, {NULL,NULL},
        };

        FillForm(form,NA_ICONS,items,widgets,callbacks);
        XtPopup(shell,XtGrabExclusive);
}

void    SetSensitive(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        XtSetSensitive((Widget)closure,True);
}
```

source/Process.c

```
/*
 *    Call sub-processes
 */

#include     "../include/xwave.h"
#include     <signal.h>
#include     <sys/wait.h>
#include     <sys/time.h>
#include     <sys/resource.h>

/*           Function Name:    Fork
 *           Description:  Executes a file in a process and waits for termination
 *           Arguments:        argv - standard argv argument description
 *           Returns:          dead process id
 */

int     Fork(argv)

char    *argv[];

{
        int     pid;
        union   wait    statusp;
        struct  rusage rusage;


        if (0==(pid=fork())) {
                execvp(argv[0],argv);
                exit();
```

```
	} else if (pid>0) wait4(pid,&statusp,0,&rusage);
	return(pid);
}

/*	Function Name:	zropen
 *	Description:	Open a file (or .Z file) for reading
 *	Arguments:	file_name - name of the file to be read
 *			pid - pointer to process id
 *	Returns:	file pointer
 */

FILE	*zropen(file_name,pid)

char	*file_name;
int	*pid;

{
	char	z_name[STRLEN];
	String	zcat[]={"zcat",z_name,NULL};
	FILE	*fp;

	if (NULL==(fp=fopen(file_name,"r"))) {
		static int	up[2];

		sprintf(z_name,"%s.Z",file_name);
		pipe(up);
		if (0!=(*pid=fork())) {
			Dprintf("Parent process started\n");
			close(up[1]);
			fp=fdopen(up[0],"r");
		} else {
			Dprintf("Running zcat on %s\n",zcat[1]);
```

```
                close(up[0]);
                dup2( up[1], 1 );
                close( up[1] );
                execvp(zcat[0],zcat);
            }
        }
        return(fp);
}

/*      Function Name:      zseek
 *      Description:   Fast-forward thru file (fseek will not work on pipes)
 *      Arguments:     fp - file pointer
 *                          bytes - bytes to skip
 */

void    zseek(fp,bytes)

FILE    *fp;
int     bytes;

{
        char    scratch[1000];
        int     i;

        while(bytes>0) {
                int     amount=bytes>1000?1000:bytes;

                fread(scratch,sizeof(char),amount,fp);
                bytes-=amount;
        }
}
```

```
void    zclose(fp,pid)

FILE    *fp;
int     pid;

{
        union  wait    statusp;
        struct  rusage rusage;

        fclose(fp);
        if (pid!=0) wait4(pid,&statusp,0,&rusage);
}
```

source/PullRightMenu.c

```
#if ( !defined(lint) && !defined(SABER) )
static char Xrcsid[] = "$XConsortium: PullRightMenu.c,v 1.32 89/12/11 15:01:50 kit
Exp $";
#endif

/*
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 *
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 * documentation for any purpose is hereby granted without fee, provided that
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```

```
 * CONNECTION WITH THE USE OR PERFORMANCE OF THIS SOFTWARE.
 */

/*
 * PullRightMenu.c - Source code file for PullRightMenu widget.
 *
 */

#include <stdio.h>
#include <X11/IntrinsicP.h>
#include <X11/StringDefs.h>

#include <X11/Xaw/XawInit.h>
#include <X11/Xaw/SimpleMenP.h>
#include "PullRightMenuP.h"
#include <X11/Xaw/SmeBSB.h>
#include "SmeBSBpr.h"
#include <X11/Xaw/Cardinals.h>

#include <X11/Xmu/Initer.h>
#include <X11/Xmu/CharSet.h>

#define streq(a, b)        ( strcmp((a), (b)) == 0 )

#define offset(field) XtOffset(PullRightMenuWidget, simple_menu.field)

static XtResource resources[] = {

/*
 * Label Resources.
 */
```

```
{XtNlabel, XtCLabel, XtRString, sizeof(String),
  offset(label_string), XtRString, NULL},
{XtNlabelClass, XtCLabelClass, XtRPointer, sizeof(WidgetClass),
  offset(label_class), XtRImmediate, (caddr_t) NULL},

/*
 * Layout Resources.
 */

{XtNrowHeight, XtCRowHeight, XtRDimension, sizeof(Dimension),
  offset(row_height), XtRImmediate, (caddr_t) 0},
{XtNtopMargin, XtCVerticalMargins, XtRDimension, sizeof(Dimension),
  offset(top_margin), XtRImmediate, (caddr_t) 0},
{XtNbottomMargin, XtCVerticalMargins, XtRDimension, sizeof(Dimension),
  offset(bottom_margin), XtRImmediate, (caddr_t) 0},

/*
 * Misc. Resources
 */

{ XtNallowShellResize, XtCAllowShellResize, XtRBoolean, sizeof(Boolean),
   XtOffset(SimpleMenuWidget, shell.allow_shell_resize),
   XtRImmediate, (XtPointer) TRUE },
{XtNcursor, XtCCursor, XtRCursor, sizeof(Cursor),
   offset(cursor), XtRImmediate, (caddr_t) None},
{XtNmenuOnScreen, XtCMenuOnScreen, XtRBoolean, sizeof(Boolean),
   offset(menu_on_screen), XtRImmediate, (caddr_t) TRUE},
{XtNpopupOnEntry, XtCPopupOnEntry, XtRWidget, sizeof(Widget),
   offset(popup_entry), XtRWidget, NULL},
{XtNbackingStore, XtCBackingStore, XtRBackingStore, sizeof (int),
   offset(backing_store),
   XtRImmediate, (caddr_t) (Always + WhenMapped + NotUseful)},
```

```
  {XtNbutton, XtCWidget, XtRWidget, sizeof(Widget),
        offset(button), XtRWidget, (XtPointer)NULL},
};
#undef offset

static char defaultTranslations[] =
   "<EnterWindow>:   highlight()     \n\
    <LeaveWindow>:   pull()          \n\
    <BtnMotion>:     highlight()     \n\
    <BtnUp>:         execute()";

/*
 * Semi Public function definitions.
 */

static void Redisplay(), Realize(), Resize(), ChangeManaged();
static void Initialize(), ClassInitialize(), ClassPartInitialize();
static Boolean SetValues(), SetValuesHook();
static XtGeometryResult GeometryManager();

/*
 * Action Routine Definitions
 */

static void Highlight(), Unhighlight(), Pull(), Execute(), Notify(), PositionMenuAction();

/*
 * Private Function Definitions.
 */

static void MakeSetValuesRequest(), CreateLabel(), Layout();
static void AddPositionAction(), PositionMenu(), ChangeCursorOnGrab();
```

```
static Dimension GetMenuWidth(), GetMenuHeight();
static Widget FindMenu();
static SmeObject GetEventEntry();

static XtActionsRec actionsList[] =
{
 {"pull",            Pull},
 {"execute",         Execute},
 {"notify",          Notify},
 {"highlight",       Highlight},
 {"unhighlight",     Unhighlight},
};

CompositeClassExtensionRec pr_extension_rec = {
    /* next_extension */ NULL,
    /* record_type */    NULLQUARK,
    /* version */        XtCompositeExtensionVersion,
    /* record_size */    sizeof(CompositeClassExtensionRec),
    /* accepts_objects */ TRUE,
};

#define superclass (&overrideShellClassRec)

PullRightMenuClassRec pullRightMenuClassRec = {
 {
  /* superclass          */ (WidgetClass) superclass,
  /* class_name          */ "PullRightMenu",
  /* size                */ sizeof(PullRightMenuRec),
  /* class_initialize    */ ClassInitialize,
  /* class_part_initialize*/ ClassPartInitialize,
  /* Class init'ed       */ FALSE,
  /* initialize          */ Initialize,
```

```
/* initialize_hook      */   NULL,
/* realize              */   Realize,
/* actions              */   actionsList,
/* num_actions          */   XtNumber(actionsList),
/* resources            */   resources,
/* resource_count       */   XtNumber(resources),
/* xrm_class            */   NULLQUARK,
/* compress_motion      */   TRUE,
/* compress_exposure    */   TRUE,
/* compress_enterleave*/     TRUE,
/* visible_interest     */   FALSE,
/* destroy              */   NULL,
/* resize               */   Resize,
/* expose               */   Redisplay,
/* set_values           */   SetValues,
/* set_values_hook      */   SetValuesHook,
/* set_values_almost    */   XtInheritSetValuesAlmost,
/* get_values_hook      */   NULL,
/* accept_focus         */   NULL,
/* intrinsics version */     XtVersion,
/* callback offsets     */   NULL,
/* tm_table             */   defaultTranslations,
/* query_geometry       */   NULL,
/* display_accelerator*/     NULL,
/* extension            */   NULL
},{
/* geometry_manager     */   GeometryManager,
/* change_managed       */   ChangeManaged,
/* insert_child         */   XtInheritInsertChild,
/* delete_child         */   XtInheritDeleteChild,
/* extension            */   NULL
},{
```

```
    /* Shell extension          */   NULL
  },{
    /* Override extension */    NULL
  },{
    /* Simple Menu extension*/  NULL
  }
};

WidgetClass pullRightMenuWidgetClass = (WidgetClass)&pullRightMenuClassRec;

/************************************************************
 *
 * Semi-Public Functions.
 *
 ************************************************************/

/*      Function Name: ClassInitialize
 *      Description: Class Initialize routine, called only once.
 *      Arguments: none.
 *      Returns: none.
 */

static void
ClassInitialize()
{
  XawInitializeWidgetSet();
  XtAddConverter( XtRString, XtRBackingStore, XmuCvtStringToBackingStore,
                  NULL, 0 );
  XmuAddInitializer( AddPositionAction, NULL);
}

/*      Function Name: ClassInitialize
```

```
 *      Description: Class Part Initialize routine. called for every
 *                   subclass.  Makes sure that the subclasses pick up
 *                   the extension record.
 *      Arguments: wc - the widget class of the subclass.
 *      Returns: none.
 */

static void
ClassPartInitialize(wc)
WidgetClass wc;
{
   SimpleMenuWidgetClass smwc = (SimpleMenuWidgetClass) wc;

/*
 * Make sure that our subclass gets the extension rec too.
 */

   pr_extension_rec.next_extension = smwc->composite_class.extension;
   smwc->composite_class.extension = (caddr_t) &pr_extension_rec;
}

/*      Function Name: Initialize
 *      Description: Initializes the simple menu widget
 *      Arguments: request - the widget requested by the argument list.
 *                 new     - the new widget with both resource and non
 *                           resource values.
 *      Returns: none.
 */

/* ARGSUSED */
static void
Initialize(request, new)
```

```
Widget request, new;
{
  SimpleMenuWidget smw = (SimpleMenuWidget) new;

  XmuCallInitializers(XtWidgetToApplicationContext(new));

  if (smw->simple_menu.label_class == NULL)
      smw->simple_menu.label_class = smeBSBObjectClass;

  smw->simple_menu.label = NULL;
  smw->simple_menu.entry_set = NULL;
  smw->simple_menu.recursive_set_values = FALSE;

  if (smw->simple_menu.label_string != NULL)
      CreateLabel(new);

  smw->simple_menu.menu_width = TRUE;

  if (smw->core.width == 0) {
      smw->simple_menu.menu_width = FALSE;
      smw->core.width = GetMenuWidth(new, NULL);
  }

  smw->simple_menu.menu_height = TRUE;

  if (smw->core.height == 0) {
      smw->simple_menu.menu_height = FALSE;
      smw->core.height = GetMenuHeight(new);
  }

/*
 * Add a popup_callback routine for changing the cursor.
```

```
*/

XtAddCallback(new, XtNpopupCallback, ChangeCursorOnGrab, NULL);
}

/*      Function Name: Redisplay
 *      Description: Redisplays the contents of the widget.
 *      Arguments: w - the simple menu widget.
 *                 event - the X event that caused this redisplay.
 *                 region - the region the needs to be repainted.
 *      Returns: none.
 */

/* ARGSUSED */
static void
Redisplay(w, event, region)
Widget w;
XEvent * event;
Region region;
{
   SimpleMenuWidget smw = (SimpleMenuWidget) w;
   SmeObject * entry;
   SmeObjectClass class;

   if (region == NULL)
       XClearWindow(XtDisplay(w), XtWindow(w));

   /*
    * Check and Paint each of the entries - including the label.
    */

   ForAllChildren(smw, entry) {
```

```
        if (!XtIsManaged ( (Widget) *entry)) continue;

        if (region != NULL)
            switch(XRectInRegion(region, (int) (*entry)->rectangle.x,
                                 (int) (*entry)->rectangle.y,
                                 (unsigned int) (*entry)->rectangle.width,
                                 (unsigned int) (*entry)->rectangle.height)) {
            case RectangleIn:
            case RectanglePart:
                break;
            default:
                continue;
            }
        class = (SmeObjectClass) (*entry)->object.widget_class;

        if (class->rect_class.expose != NULL)
            (class->rect_class.expose)( (Widget) *entry, NULL, NULL);
    }
}

/*      Function Name: Realize
 *      Description: Realizes the widget.
 *      Arguments: w - the simple menu widget.
 *                 mask - value mask for the window to create.
 *                 attrs - attributes for the window to create.
 *      Returns: none
 */

static void
Realize(w, mask, attrs)
Widget w;
XtValueMask * mask;
```

```
XSetWindowAttributes * attrs;
{
   SimpleMenuWidget smw = (SimpleMenuWidget) w;

   attrs->cursor = smw->simple_menu.cursor;
   *mask |= CWCursor;
   if ((smw->simple_menu.backing_store == Always) ||
       (smw->simple_menu.backing_store == NotUseful) ||
       (smw->simple_menu.backing_store == WhenMapped) ) {
       *mask |= CWBackingStore;
       attrs->backing_store = smw->simple_menu.backing_store;
   }
   else
       *mask &= ~CWBackingStore;

   (*superclass->core_class.realize) (w, mask, attrs);
}

/*      Function Name: Resize
 *      Description: Handle the menu being resized bigger.
 *      Arguments: w - the simple menu widget.
 *      Returns: none.
 */

static void
Resize(w)
Widget w;
{
   SimpleMenuWidget smw = (SimpleMenuWidget) w;
   SmeObject * entry;

   if ( !XtIsRealized(w) ) return;
```

```
    ForAllChildren(smw, entry)       /* reset width of all entries. */
        if (XtIsManaged( (Widget) *entry))
            (*entry)->rectangle.width = smw->core.width;

    Redisplay(w, (XEvent *) NULL, (Region) NULL);
}

/*      Function Name: SetValues
 *      Description: Relayout the menu when one of the resources is changed.
 *      Arguments: current - current state of the widget.
 *                 request - what was requested.
 *                 new - what the widget will become.
 *      Returns: none
 */

/* ARGSUSED */
static Boolean
SetValues(current, request, new)
Widget current, request, new;
{
    SimpleMenuWidget smw_old = (SimpleMenuWidget) current;
    SimpleMenuWidget smw_new = (SimpleMenuWidget) new;
    Boolean ret_val = FALSE, layout = FALSE;

    if (!XtIsRealized(current)) return(FALSE);

    if (!smw_new->simple_menu.recursive_set_values) {
        if (smw_new->core.width != smw_old->core.width) {
            smw_new->simple_menu.menu_width = (smw_new->core.width != 0);
            layout = TRUE;
        }
        if (smw_new->core.height != smw_old->core.height) {
```

```
            smw_new->simple_menu.menu_height = (smw_new->core.height != 0);
            layout = TRUE;
        }
    }

    if (smw_old->simple_menu.cursor != smw_new->simple_menu.cursor)
        XDefineCursor(XtDisplay(new),
                      XtWindow(new), smw_new->simple_menu.cursor);

    if (smw_old->simple_menu.label_string !=smw_new->simple_menu.label_string)
        if (smw_new->simple_menu.label_string == NULL)        /* Destroy. */
            XtDestroyWidget(smw_old->simple_menu.label);
        else if (smw_old->simple_menu.label_string == NULL)   /* Create. */
            CreateLabel(new);
        else {                                                /* Change. */
            Arg args[1];

            XtSetArg(args[0], XtNlabel, smw_new->simple_menu.label_string);
            XtSetValues(smw_new->simple_menu.label, args, ONE);
        }

    if (smw_old->simple_menu.label_class != smw_new->simple_menu.label_class)
        XtAppWarning(XtWidgetToApplicationContext(new),
                     "No Dynamic class change of the SimpleMenu Label.");

    if ((smw_old->simple_menu.top_margin != smw_new->simple_menu.top_margin)
||
        (smw_old->simple_menu.bottom_margin !=
         smw_new->simple_menu.bottom_margin) /* filler................ */ ) {
        layout = TRUE;
        ret_val = TRUE;
    }
```

```
    if (layout)
        Layout(new, NULL, NULL);

    return(ret_val);
}

/*      Function Name: SetValuesHook
 *      Description: To handle a special case, this is passed the
 *                   actual arguments.
 *      Arguments: w - the menu widget.
 *                 arglist - the argument list passed to XtSetValues.
 *                 num_args - the number of args.
 *      Returns: none
 */

/*
 * If the user actually passed a width and height to the widget
 * then this MUST be used, rather than our newly calculated width and
 * height.
 */

static Boolean
SetValuesHook(w, arglist, num_args)
Widget w;
ArgList arglist;
Cardinal *num_args;
{
    register Cardinal i;
    Dimension width, height;

    width = w->core.width;
    height = w->core.height;
```

```
    for ( i = 0 ; i < *num_args ; i++) {
        if ( streq(arglist[i].name, XtNwidth) )
            width = (Dimension) arglist[i].value;
        if ( streq(arglist[i].name, XtNheight) )
            height = (Dimension) arglist[i].value;
    }

    if ((width != w->core.width) || (height != w->core.height))
        MakeSetValuesRequest(w, width, height);
    return(FALSE);
}

/****************************************************************
 *
 * Geometry Management routines.
 *
 ****************************************************************/

/*      Function Name: GeometryManager
 *      Description: This is the SimpleMenu Widget's Geometry Manager.
 *      Arguments: w - the Menu Entry making the request.
 *                 request - requested new geometry.
 *                 reply - the allowed geometry.
 *      Returns: XtGeometry{Yes, No, Almost}.
 */

static XtGeometryResult
GeometryManager(w, request, reply)
Widget w;
XtWidgetGeometry * request, * reply;
{
```

```
    SimpleMenuWidget smw = (SimpleMenuWidget) XtParent(w);
    SmeObject entry = (SmeObject) w;
    XtGeometryMask mode = request->request_mode;
    XtGeometryResult answer;
    Dimension old_height, old_width;

    if ( !(mode & CWWidth) && !(mode & CWHeight) )
        return(XtGeometryNo);

    reply->width = request->width;
    reply->height = request->height;

    old_width = entry->rectangle.width;
    old_height = entry->rectangle.height;

    Layout(w, &(reply->width), &(reply->height) );

/*
 * Since we are an override shell and have no parent there is no one to
 * ask to see if this geom change is okay, so I am just going to assume
 * we can do whatever we want.  If you subclass be very careful with this
 * assumption, it could bite you.
 *
 * Chris D. Peterson - Sept. 1989.
 */

    if ( (reply->width == request->width) &&
         (reply->height == request->height) ) {

        if ( mode & XtCWQueryOnly ) { /* Actually perform the layout. */
            entry->rectangle.width = old_width;
            entry->rectangle.height = old_height;
```

```
        }
        else {
            Layout(( Widget) smw, NULL, NULL);
        }
        answer = XtGeometryDone;
    }
    else {
        entry->rectangle.width = old_width;
        entry->rectangle.height = old_height;

        if ( ((reply->width == request->width) && !(mode & CWHeight)) ||
             ((reply->height == request->height) && !(mode & CWWidth)) ||
             ((reply->width == request->width) &&
              (reply->height == request->height)) )
            answer = XtGeometryNo;
        else {
            answer = XtGeometryAlmost;
            reply->request_mode = 0;
            if (reply->width != request->width)
                reply->request_mode |= CWWidth;
            if (reply->height != request->height)
                reply->request_mode |= CWHeight;
        }
    }
    return(answer);
}

/*      Function Name: ChangeManaged
 *      Description: called whenever a new child is managed.
 *      Arguments: w - the simple menu widget.
 *      Returns: none.
 */
```

```
static void
ChangeManaged(w)
Widget w;
{
   Layout(w, NULL, NULL);
}

/*****************************************************************
 *
 * Global Action Routines.
 *
 * These actions routines will be added to the application's
 * global action list.
 *
 *****************************************************************/

/*      Function Name: PositionMenuAction
 *      Description: Positions the simple menu widget.
 *      Arguments: w - a widget (no the simple menu widget.)
 *                 event - the event that caused this action.
 *                 params, num_params - parameters passed to the routine.
 *                                     we expect the name of the menu here.
 *      Returns: none
 */

/* ARGSUSED */
static void
PositionMenuAction(w, event, params, num_params)
Widget w;
XEvent * event;
String * params;
Cardinal * num_params;
```

```
{
  Widget menu;
  XPoint loc;

  if (*num_params != 1) {
    char error_buf[BUFSIZ];
    sprintf(error_buf, "%s %s",
            "Xaw - SimpleMenuWidget: position menu action expects only one",
            "parameter which is the name of the menu.");
    XtAppWarning(XtWidgetToApplicationContext(w), error_buf);
    return;
  }

  if ( (menu = FindMenu(w, params[0])) == NULL) {
    char error_buf[BUFSIZ];
    sprintf(error_buf, "%s '%s'",
            "Xaw - SimpleMenuWidget: could not find menu named: ", params[0]);
    XtAppWarning(XtWidgetToApplicationContext(w), error_buf);
    return;
  }

  switch (event->type) {
  case ButtonPress:
  case ButtonRelease:
    loc.x = event->xbutton.x_root;
    loc.y = event->xbutton.y_root;
    PositionMenu(menu, &loc);
    break;
  case EnterNotify:
  case LeaveNotify:
    loc.x = event->xcrossing.x_root;
    loc.y = event->xcrossing.y_root;
```

```
    PositionMenu(menu, &loc);
    break;
  case MotionNotify:
    loc.x = event->xmotion.x_root;
    loc.y = event->xmotion.y_root;
    PositionMenu(menu, &loc);
    break;
  default:
    PositionMenu(menu, NULL);
    break;
  }
}

/****************************************************************
 *
 * Widget Action Routines.
 *
 ****************************************************************/

/*      Function Name: Unhighlight
 *      Description: Unhighlights current entry.
 *      Arguments: w - the simple menu widget.
 *                 event - the event that caused this action.
 *                 params, num_params - ** NOT USED **
 *      Returns: none
 */

/* ARGSUSED */
static void
Unhighlight(w, event, params, num_params)
Widget w;
XEvent * event;
```

```
String * params;
Cardinal * num_params;
{
    SimpleMenuWidget smw = (SimpleMenuWidget) w;
    SmeObject entry = smw->simple_menu.entry_set;
    SmeObjectClass class;

    if ( entry == NULL) return;

    smw->simple_menu.entry_set = NULL;
    class = (SmeObjectClass) entry->object.widget_class;
    (class->sme_class.unhighlight) ( (Widget) entry);
}

/*      Function Name: Highlight
 *      Description: Highlights current entry.
 *      Arguments: w - the simple menu widget.
 *                 event - the event that caused this action.
 *                 params, num_params - ** NOT USED **
 *      Returns: none
 */

/* ARGSUSED */
static void
Highlight(w, event, params, num_params)
Widget w;
XEvent * event;
String * params;
Cardinal * num_params;
{
    SimpleMenuWidget smw = (SimpleMenuWidget) w;
    SmeObject entry;
```

```
    SmeObjectClass class;

    if ( !XtIsSensitive(w) ) return;

    entry = GetEventEntry(w, event);

    if (entry == smw->simple_menu.entry_set) return;

    Unhighlight(w, event, params, num_params);

    if (entry == NULL) return;

    if ( !XtIsSensitive( (Widget) entry)) {
        smw->simple_menu.entry_set = NULL;
        return;
    }

    smw->simple_menu.entry_set = entry;
    class = (SmeObjectClass) entry->object.widget_class;

    (class->sme_class.highlight) ( (Widget) entry);
}

/*    Function Name: Notify
 *    Description: Notify user of current entry.
 *    Arguments: w - the simple menu widget.
 *               event - the event that caused this action.
 *               params, num_params - ** NOT USED **
 *    Returns: none
 */

/* ARGSUSED */
```

```
static void
Notify(w, event, params, num_params)
Widget w;
XEvent * event;
String * params;
Cardinal * num_params;
{
   SimpleMenuWidget smw = (SimpleMenuWidget) w;
   SmeObject entry = smw->simple_menu.entry_set;
   SmeObjectClass class;

   if ( (entry == NULL) || !XtIsSensitive((Widget) entry) ) return;

   class = (SmeObjectClass) entry->object.widget_class;
   (class->sme_class.notify)( (Widget) entry );
}

/*     Function Name: Pull
 *     Description: Determines action on basis of leave direction.
 *     Arguments: w - the pull right menu widget.
 *                event - the LeaveWindow event that caused this action.
 *                params, num_params - ** NOT USED **
 *     Returns: none
 */

static void Pull(w, event, params, num_params)

Widget       w;
XEvent       *event;
String  *params;
Cardinal     *num_params;
```

```
{
        PullRightMenuWidget      prw=(PullRightMenuWidget)w;
        SmeObject   entry=prw->simple_menu.entry_set;
        SmeObjectClass     class;

        if ((entry==NULL)||!XtIsSensitive((Widget)entry))return;
        if (event->type!=LeaveNotify && event->type!=EnterNotify) {
                XtAppError(XtWidgetToApplicationContext(w),
                  "pull() action should only be used with XCrossing events.");
                return;
        }
        if (None!=event->xcrossing.subwindow) return;
        if (event->xcrossing.y<0 || event->xcrossing.y>prw->core.height) {
                Unhighlight(w,event,params,num_params);
                return;
        };
        if (event->xcrossing.x<0) {
                if (XtIsSubclass(XtParent(w),pullRightMenuWidgetClass)) XtPopdown(w);
                return;
        };
    class=(SmeObjectClass)entry->object.widget_class;
        if (event->xcrossing.x>prw->core.width &&
XtIsSubclass(entry,smeBSBprObjectClass)) (class->sme_class.notify)((Widget)entry);
        else Unhighlight(w,event,params,num_params);
}

/*      Function Name: Execute
 *      Description: Determines notify action on basis of SmeObject.
 *      Arguments: w - the pull right menu widget.
 *                 event - the notify-type event that caused this action.
 *                 params, num_params - ** NOT USED **
 *      Returns: none
```

```
*/

static void Execute(w, event, params, num_params)

Widget      w;
XEvent      *event;
String  *params;
Cardinal    *num_params;

{
        PullRightMenuWidget     prw=(PullRightMenuWidget)w;
        SmeObject   entry=prw->simple_menu.entry_set;
        SmeObjectClass      class;
        Widget      shell;

        Dprintf("Execute\n");
        for(shell=w;XtIsSubclass(shell,pullRightMenuWidgetClass);shell=XtParent(shell))
{
                XawSimpleMenuClearActiveEntry(shell);
                XtPopdown(shell);
        };
        if
((entry==GetEventEntry(w,event))&&(entry!=NULL)&&XtIsSensitive((Widget)entry)) {
                class=(SmeObjectClass)entry->object.widget_class;
                if (XtIsSubclass(entry,smeBSBObjectClass))
(class->sme_class.notify)((Widget)entry);
        };
}


/***************************************************************
```

```
 *
 * Public Functions.
 *
 ***************************************************************/

/*      Function Name: XawPullRightMenuAddGlobalActions
 *      Description: adds the global actions to the simple menu widget.
 *      Arguments: app_con - the appcontext.
 *      Returns: none.
 */

void
XawPullRightMenuAddGlobalActions(app_con)
XtAppContext app_con;
{
   XtInitializeWidgetClass(pullRightMenuWidgetClass);
   XmuCallInitializers( app_con );
}

/***************************************************************
 *
 * Private Functions.
 *
 ***************************************************************/

/*      Function Name: CreateLabel
 *      Description: Creates a the menu label.
 *      Arguments: w - the smw widget.
 *      Returns: none.
 *
 * Creates the label object and makes sure it is the first child in
 * in the list.
```

```
*/

static void
CreateLabel(w)
Widget w;
{
  SimpleMenuWidget smw = (SimpleMenuWidget) w;
  register Widget * child, * next_child;
  register int i;
  Arg args[2];

  if ( (smw->simple_menu.label_string == NULL) ||
       (smw->simple_menu.label != NULL) ) {
    char error_buf[BUFSIZ];

    sprintf(error_buf, "Xaw Simple Menu Widget: %s or %s, %s",
            "label string is NULL", "label already exists",
            "no label is being created.");
    XtAppWarning(XtWidgetToApplicationContext(w), error_buf);
    return;
  }

  XtSetArg(args[0], XtNlabel, smw->simple_menu.label_string);
  XtSetArg(args[1], XtNjustify, XtJustifyCenter);
  smw->simple_menu.label = (SmeObject)
                    XtCreateManagedWidget("menuLabel",
                              smw->simple_menu.label_class, w,
                              args, TWO);

  next_child = NULL;
  for (child = smw->composite.children + smw->composite.num_children,
       i = smw->composite.num_children ; i > 0 ; i--, child--) {
```

```
        if (next_child != NULL)
            *next_child = *child;
        next_child = child;
    }
    *child = (Widget) smw->simple_menu.label;
}

/*      Function Name: Layout
 *      Description: lays the menu entries out all nice and neat.
 *      Arguments: w - See below (+++)
 *                 width_ret, height_ret - The returned width and
 *                                         height values.
 *      Returns: none.
 *
 * if width == NULL || height == NULL then it assumes the you do not care
 * about the return values, and just want a relayout.
 *
 * if this is not the case then it will set width_ret and height_ret
 * to be width and height that the child would get if it were layed out
 * at this time.
 *
 * +++ "w" can be the simple menu widget or any of its object children.
 */

static void
Layout(w, width_ret, height_ret)
Widget w;
Dimension *width_ret, *height_ret;
{
    SmeObject current_entry, *entry;
    SimpleMenuWidget smw;
    Dimension width, height;
```

```
Boolean do_layout = ((height_ret == NULL) || (width_ret == NULL));
Boolean allow_change_size;
height = 0;

if ( XtIsSubclass(w, pullRightMenuWidgetClass) ) {
    smw = (SimpleMenuWidget) w;
    current_entry = NULL;
}
else {
    smw = (SimpleMenuWidget) XtParent(w);
    current_entry = (SmeObject) w;
}

allow_change_size = (!XtIsRealized((Widget)smw) ||
                    (smw->shell.allow_shell_resize));

if ( smw->simple_menu.menu_height )
    height = smw->core.height;
else
    if (do_layout) {
        height = smw->simple_menu.top_margin;
        ForAllChildren(smw, entry) {
            if (!XtIsManaged( (Widget) *entry)) continue;

            if ( (smw->simple_menu.row_height != 0) &&
                (*entry != smw->simple_menu.label) )
                (*entry)->rectangle.height = smw->simple_menu.row_height;

            (*entry)->rectangle.y = height;
            (*entry)->rectangle.x = 0;
            height += (*entry)->rectangle.height;
        }
```

```
            height += smw->simple_menu.bottom_margin;
        }
        else {
            if ((smw->simple_menu.row_height != 0) &&
                (current_entry != smw->simple_menu.label) )
                height = smw->simple_menu.row_height;
        }

    if (smw->simple_menu.menu_width)
        width = smw->core.width;
    else if ( allow_change_size )
        width = GetMenuWidth((Widget) smw, (Widget) current_entry);
    else
        width = smw->core.width;

    if (do_layout) {
        ForAllChildren(smw, entry)
            if (XtIsManaged( (Widget) *entry))
                (*entry)->rectangle.width = width;

        if (allow_change_size)
            MakeSetValuesRequest((Widget) smw, width, height);
    }
    else {
        *width_ret = width;
        if (height != 0)
            *height_ret = height;
    }
}

/*      Function Name: AddPositionAction
 *      Description: Adds the XawPositionSimpleMenu action to the global
```

```
*              action list for this appcon.
*     Arguments: app_con - the application context for this app.
*              data - NOT USED.
*     Returns: none.
*/

/* ARGSUSED */
static void
AddPositionAction(app_con, data)
XtAppContext app_con;
caddr_t data;
{
   static XtActionsRec pos_action[] = {
      { "XawPositionSimpleMenu", PositionMenuAction },
   };

   XtAppAddActions(app_con, pos_action, XtNumber(pos_action));
}

/*    Function Name: FindMenu
 *    Description: Find the menu give a name and reference widget.
 *    Arguments: widget - reference widget.
 *               name   - the menu widget's name.
 *    Returns: the menu widget or NULL.
 */

static Widget
FindMenu(widget, name)
Widget widget;
String name;
{
   register Widget w, menu;
```

```
    for ( w = widget ; w != NULL ; w = XtParent(w) )
        if ( (menu = XtNameToWidget(w, name)) != NULL )
            return(menu);
    return(NULL);
}

/*      Function Name: PositionMenu
 *      Description: Places the menu
 *      Arguments: w - the simple menu widget.
 *                 location - a pointer the the position or NULL.
 *      Returns: none.
 */

static void
PositionMenu(w, location)
Widget w;
XPoint * location;
{
    SimpleMenuWidget smw = (SimpleMenuWidget) w;
    SmeObject entry;
    XPoint t_point;
    static void MoveMenu();

    if (location == NULL) {
        Window junk1, junk2;
        int root_x, root_y, junkX, junkY;
        unsigned int junkM;

        location = &t_point;
        if (XQueryPointer(XtDisplay(w), XtWindow(w), &junk1, &junk2,
                          &root_x, &root_y, &junkX, &junkY, &junkM) == FALSE) {
```

```
        char error_buf[BUFSIZ];
        sprintf(error_buf, "%s %s", "Xaw - SimpleMenuWidget:",
                "Could not find location of mouse pointer");
        XtAppWarning(XtWidgetToApplicationContext(w), error_buf);
        return;
      }
      location->x = (short) root_x;
      location->y = (short) root_y;
    }

    /*
     * The width will not be correct unless it is realized.
     */

    XtRealizeWidget(w);

    location->x -= (Position) w->core.width/2;

    if (smw->simple_menu.popup_entry == NULL)
        entry = smw->simple_menu.label;
    else
        entry = smw->simple_menu.popup_entry;

    if (entry != NULL)
        location->y -= entry->rectangle.y + entry->rectangle.height/2;

    MoveMenu(w, (Position) location->x, (Position) location->y);
}

/*      Function Name: MoveMenu
 *      Description: Actually moves the menu, may force it to
 *                   to be fully visable if menu_on_screen is TRUE.
```

```
*      Arguments: w - the simple menu widget.
*                 x, y - the current location of the widget.
*      Returns: none
*/

static void
MoveMenu(w, x, y)
Widget w;
Position x, y;
{
    Arg arglist[2];
    Cardinal num_args = 0;
    SimpleMenuWidget smw = (SimpleMenuWidget) w;

    if (smw->simple_menu.menu_on_screen) {
        int width = w->core.width + 2 * w->core.border_width;
        int height = w->core.height + 2 * w->core.border_width;

        if (x < 0)
            x = 0;
        else {
            int scr_width = WidthOfScreen(XtScreen(w));
            if (x + width > scr_width)
                x = scr_width - width;
        }

        if (y < 0)
            y = 0;
        else {
            int scr_height = HeightOfScreen(XtScreen(w));
            if (y + height > scr_height)
                y = scr_height - height;
```

```
        }
    }

    XtSetArg(arglist[num_args], XtNx, x); num_args++;
    XtSetArg(arglist[num_args], XtNy, y); num_args++;
    XtSetValues(w, arglist, num_args);
}

/*      Function Name: ChangeCursorOnGrab
 *      Description: Changes the cursor on the active grab to the one
 *                   specified in out resource list.
 *      Arguments: w - the widget.
 *                 junk, garbage - ** NOT USED **.
 *      Returns: None.
 */

/* ARGSUSED */
static void
ChangeCursorOnGrab(w, junk, garbage)
Widget w;
caddr_t junk, garbage;
{
    SimpleMenuWidget smw = (SimpleMenuWidget) w;

    /*
     * The event mask here is what is currently in the MIT implementation.
     * There really needs to be a way to get the value of the mask out
     * of the toolkit (CDP 5/26/89).
     */

    XChangeActivePointerGrab(XtDisplay(w), ButtonPressMask|ButtonReleaseMask,
                             smw->simple_menu.cursor, CurrentTime);
```

```
}

/*   Function Name: MakeSetValuesRequest
 *   Description: Makes a (possibly recursive) call to SetValues,
 *                I take great pains to not go into an infinite loop.
 *   Arguments: w - the simple menu widget.
 *              width, height - the size of the ask for.
 *   Returns: none
 */

static void
MakeSetValuesRequest(w, width, height)
Widget w;
Dimension width, height;
{
    SimpleMenuWidget smw = (SimpleMenuWidget) w;
    Arg arglist[2];
    Cardinal num_args = (Cardinal) 0;

    if ( !smw->simple_menu.recursive_set_values ) {
        if ( (smw->core.width != width) || (smw->core.height != height) ) {
            smw->simple_menu.recursive_set_values = TRUE;
            XtSetArg(arglist[num_args], XtNwidth, width);   num_args++;
            XtSetArg(arglist[num_args], XtNheight, height); num_args++;
            XtSetValues(w, arglist, num_args);
        }
        else if (XtIsRealized( (Widget) smw))
            Redisplay((Widget) smw, (XEvent *) NULL, (Region) NULL);
    }
    smw->simple_menu.recursive_set_values = FALSE;
}
```

```
/*      Function Name: GetMenuWidth
 *      Description: Sets the length of the widest entry in pixels.
 *      Arguments: w - the simple menu widget.
 *      Returns: width of menu.
 */

static Dimension
GetMenuWidth(w, w_ent)
Widget w, w_ent;
{
    SmeObject cur_entry = (SmeObject) w_ent;
    SimpleMenuWidget smw = (SimpleMenuWidget) w;
    Dimension width, widest = (Dimension) 0;
    SmeObject * entry;

    if ( smw->simple_menu.menu_width )
        return(smw->core.width);

    ForAllChildren(smw, entry) {
        XtWidgetGeometry preferred;

        if (!XtIsManaged( (Widget) *entry)) continue;

        if (*entry != cur_entry) {
            XtQueryGeometry(*entry, NULL, &preferred);

            if (preferred.request_mode & CWWidth)
                width = preferred.width;
            else
                width = (*entry)->rectangle.width;
        }
        else
```

```
            width = (*entry)->rectangle.width;

        if ( width > widest )
            widest = width;
    }

    return(widest);
}

/*      Function Name: GetMenuHeight
 *      Description: Sets the length of the widest entry in pixels.
 *      Arguments: w - the simple menu widget.
 *      Returns: width of menu.
 */

static Dimension
GetMenuHeight(w)
Widget w;
{
    SimpleMenuWidget smw = (SimpleMenuWidget) w;
    SmeObject * entry;
    Dimension height;

    if (smw->simple_menu.menu_height)
        return(smw->core.height);

    height = smw->simple_menu.top_margin + smw->simple_menu.bottom_margin;

    if (smw->simple_menu.row_height == 0)
        ForAllChildren(smw, entry)
            if (XtIsManaged ((Widget) *entry))
                height += (*entry)->rectangle.height;
```

```
    else
        height += smw->simple_menu.row_height * smw->composite.num_children;

    return(height);
}

/*      Function Name: GetEventEntry
 *      Description: Gets an entry given an event that has X and Y coords.
 *      Arguments: w - the simple menu widget.
 *                 event - the event.
 *      Returns: the entry that this point is in.
 */

static SmeObject
GetEventEntry(w, event)
Widget w;
XEvent * event;
{
    Position x_loc, y_loc;
    SimpleMenuWidget smw = (SimpleMenuWidget) w;
    SmeObject * entry;

    switch (event->type) {
    case MotionNotify:
        x_loc = event->xmotion.x;
        y_loc = event->xmotion.y;
        break;
    case EnterNotify:
    case LeaveNotify:
        x_loc = event->xcrossing.x;
        y_loc = event->xcrossing.y;
        break;
```

```
    case ButtonPress:
    case ButtonRelease:
        x_loc = event->xbutton.x;
        y_loc = event->xbutton.y;
        break;
    default:
        XtAppError(XtWidgetToApplicationContext(w),
                "Unknown event type in GetEventEntry().");
        break;
    }

    if ( (x_loc < 0) || (x_loc >= smw->core.width) || (y_loc < 0) ||
        (y_loc >= smw->core.height) )
        return(NULL);

    ForAllChildren(smw, entry) {
        if (!XtIsManaged ((Widget) *entry)) continue;

        if ( ((*entry)->rectangle.y < y_loc) &&
            ((*entry)->rectangle.y + (*entry)->rectangle.height > y_loc) )
            if ( *entry == smw->simple_menu.label )
                return(NULL);       /* cannot select the label. */
            else
                return(*entry);
    }

    return(NULL);
}
```

source/Select.c

```
/*
 * Selection from list widget
 *
 */

#include    "../include/xwave.h"

void   Select(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        Selection    sel=(Selection)closure;
        Widget       button=FindWidget(sel->button,w),
                     shell=ShellWidget(sel->name,button,SW_below,NULL,NULL),
                     form=FormatWidget("sel_form",shell), list_widget, widgets[3];
        String  *list=(sel->list_proc)();
        FormItem     items[]={
                {"sel_cancel","close",0,0,FW_icon,NULL},
                {"sel_label",(String)sel->action_name,1,0,FW_label,NULL},
                {"sel_view",NULL,0,2,FW_view,NULL},
        };
        XtCallbackRec        list_calls[]={
                {Destroy,(caddr_t)shell},
                {sel->action_proc,sel->action_closure},
                {NULL,NULL},
        }, callbacks[]={
```

```
		{Destroy,(caddr_t)shell},
		{NULL,NULL},
	};
	Arg	args[1];

	FillForm(form,THREE,items,widgets,callbacks);
	XtSetArg(args[0],XtNlist,list);

list_widget=XtCreateManagedWidget("sel_list",listWidgetClass,widgets[2],args,ONE);
	XtAddCallbacks(list_widget,XtNcallback,list_calls);
	XtPopup(shell,XtGrabExclusive);
}
```

source/SmeBSBpr.c

```
#if ( !defined(lint) && !defined(SABER) )
static char Xrcsid[] = "$XConsortium: SmeBSB.c,v 1.9 89/12/13 15:42:48 kit Exp $";
#endif

/*
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```

```
*/

/*
 * SmeBSBpr.c - Source code file for BSB pull-right Menu Entry object.
 *
 */

#include <stdio.h>
#include <X11/IntrinsicP.h>
#include <X11/StringDefs.h>

#include <X11/Xmu/Drawing.h>

#include <X11/Xaw/XawInit.h>
#include <X11/Xaw/SimpleMenu.h>
#include "SmeBSBprP.h"
#include <X11/Xaw/Cardinals.h>

#define ONE_HUNDRED 100

#define offset(field) XtOffset(SmeBSBprObject, sme_bsb.field)

static XtResource resources[] = {
  {XtNlabel,  XtCLabel, XtRString, sizeof(String),
    offset(label), XtRString, NULL},
  {XtNvertSpace,  XtCVertSpace, XtRInt, sizeof(int),
    offset(vert_space), XtRImmediate, (caddr_t) 25},
  {XtNleftBitmap, XtCLeftBitmap, XtRPixmap, sizeof(Pixmap),
    offset(left_bitmap), XtRImmediate, (caddr_t)None},
  {XtNjustify, XtCJustify, XtRJustify, sizeof(XtJustify),
    offset(justify), XtRImmediate, (caddr_t) XtJustifyLeft},
  {XtNrightBitmap, XtCRightBitmap, XtRPixmap, sizeof(Pixmap),
```

```
  offset(right_bitmap), XtRImmediate, (caddr_t)None},
 {XtNleftMargin, XtCHorizontalMargins, XtRDimension, sizeof(Dimension),
   offset(left_margin), XtRImmediate, (caddr_t) 4},
 {XtNrightMargin, XtCHorizontalMargins, XtRDimension, sizeof(Dimension),
   offset(right_margin), XtRImmediate, (caddr_t) 4},
 {XtNforeground, XtCForeground, XtRPixel, sizeof(Pixel),
   offset(foreground), XtRString, "XtDefaultForeground"},
 {XtNfont, XtCFont, XtRFontStruct, sizeof(XFontStruct *),
   offset(font), XtRString, "XtDefaultFont"},
 {XtNmenuName, XtCMenuName, XtRString, sizeof(String),
       offset(menu_name), XtRString, (caddr_t)"menu"},
};
#undef offset

/*
 * Semi Public function definitions.
 */

static void Redisplay(), Destroy(), Initialize(), FlipColors(), PopupMenu();
static void ClassInitialize();
static Boolean SetValues();
static XtGeometryResult QueryGeometry();

/*
 * Private Function Definitions.
 */

static void GetDefaultSize(), DrawBitmaps(), GetBitmapInfo();
static void CreateGCs(), DestroyGCs();

#define superclass (&smeClassRec)
SmeBSBprClassRec smeBSBprClassRec = {
```

```
{
 /* superclass          */  (WidgetClass) superclass,
 /* class_name          */  "SmeBSBpr",
 /* size                */  sizeof(SmeBSBprRec),
 /* class_initializer   */  ClassInitialize,
 /* class_part_initialize*/ NULL,
 /* Class init'ed       */  FALSE,
 /* initialize          */  Initialize,
 /* initialize_hook     */  NULL,
 /* realize             */  NULL,
 /* actions             */  NULL,
 /* num_actions         */  ZERO,
 /* resources           */  resources,
 /* resource_count      */  XtNumber(resources),
 /* xrm_class           */  NULLQUARK,
 /* compress_motion     */  FALSE,
 /* compress_exposure   */  FALSE,
 /* compress_enterleave*/   FALSE,
 /* visible_interest    */  FALSE,
 /* destroy             */  Destroy,
 /* resize              */  NULL,
 /* expose              */  Redisplay,
 /* set_values          */  SetValues,
 /* set_values_hook     */  NULL,
 /* set_values_almost   */  XtInheritSetValuesAlmost,
 /* get_values_hook     */  NULL,
 /* accept_focus        */  NULL,
 /* intrinsics version  */  XtVersion,
 /* callback offsets    */  NULL,
 /* tm_table            */  NULL,
 /* query_geometry      */  QueryGeometry,
 /* display_accelerator*/   NULL,
```

```
  /* extension          */   NULL
 },{
  /* Menu Entry Fields */

  /* highlight */           FlipColors,
  /* unhighlight */         FlipColors,
  /* notify */              PopupMenu,
  /* extension          */   NULL
 }, {
  /* BSB pull-right Menu entry Fields */

  /* extension          */   NULL
 }
};

WidgetClass smeBSBprObjectClass = (WidgetClass) &smeBSBprClassRec;

/*************************************************************
 *
 * Semi-Public Functions.
 *
 *************************************************************/

/*     Function Name: ClassInitialize
 *     Description: Initializes the SmeBSBprObject.
 *     Arguments: none.
 *     Returns: none.
 */

static void
ClassInitialize()
{
```

```
    XawInitializeWidgetSet();
    XtAddConverter( XtRString, XtRJustify, XmuCvtStringToJustify, NULL, 0 );
}

/*      Function Name: Initialize
 *      Description: Initializes the simple menu widget
 *      Arguments: request - the widget requested by the argument list.
 *                 new     - the new widget with both resource and non
 *                           resource values.
 *      Returns: none.
 */

/* ARGSUSED */
static void
Initialize(request, new)
Widget request, new;
{
    SmeBSBprObject entry = (SmeBSBprObject) new;

    if (entry->sme_bsb.label == NULL)
        entry->sme_bsb.label = XtName(new);
    else
        entry->sme_bsb.label = XtNewString( entry->sme_bsb.label );

        /* Xaw bug - bitmap initialization now performed */
    if (entry->sme_bsb.left_bitmap != None) GetBitmapInfo(entry, TRUE);
    if (entry->sme_bsb.right_bitmap != None) GetBitmapInfo(entry, FALSE);

    CreateGCs(new);
    GetDefaultSize(new, &(entry->rectangle.width), &(entry->rectangle.height));
}
```

```
/*    Function Name: Destroy
 *    Description: Called at destroy time, cleans up.
 *    Arguments: w - the simple menu widget.
 *    Returns: none.
 */

static void
Destroy(w)
Widget w;
{
   SmeBSBprObject entry = (SmeBSBprObject) w;

   DestroyGCs(w);
   if (entry->sme_bsb.label != XtName(w))
       XtFree(entry->sme_bsb.label);
}

/*    Function Name: Redisplay
 *    Description: Redisplays the contents of the widget.
 *    Arguments: w - the simple menu widget.
 *               event - the X event that caused this redisplay.
 *               region - the region the needs to be repainted.
 *    Returns: none.
 */

/* ARGSUSED */
static void
Redisplay(w, event, region)
Widget w;
XEvent * event;
Region region;
{
```

```
GC gc;
SmeBSBprObject entry = (SmeBSBprObject) w;
int font_ascent, font_descent, y_loc;

entry->sme_bsb.set_values_area_cleared = FALSE;
font_ascent = entry->sme_bsb.font->max_bounds.ascent;
font_descent = entry->sme_bsb.font->max_bounds.descent;

y_loc = entry->rectangle.y;

if (XtIsSensitive(w) && XtIsSensitive( XtParent(w) ) ) {
    if ( w == XawSimpleMenuGetActiveEntry(XtParent(w)) ) {
        XFillRectangle(XtDisplayOfObject(w), XtWindowOfObject(w),
                       entry->sme_bsb.norm_gc, 0, y_loc,
                       (unsigned int) entry->rectangle.width,
                       (unsigned int) entry->rectangle.height);
        gc = entry->sme_bsb.rev_gc;
    }
    else
        gc = entry->sme_bsb.norm_gc;
}
else
    gc = entry->sme_bsb.norm_gray_gc;

if (entry->sme_bsb.label != NULL) {
    int x_loc = entry->sme_bsb.left_margin;
    int len = strlen(entry->sme_bsb.label);
    char * label = entry->sme_bsb.label;

    switch(entry->sme_bsb.justify) {
        int width, t_width;
```

```
        case XtJustifyCenter:
            t_width = XTextWidth(entry->sme_bsb.font, label, len);
            width = entry->rectangle.width - (entry->sme_bsb.left_margin +
                                    entry->sme_bsb.right_margin);
            x_loc += (width - t_width)/2;
            break;
        case XtJustifyRight:
            t_width = XTextWidth(entry->sme_bsb.font, label, len);
            x_loc = entry->rectangle.width - (entry->sme_bsb.right_margin +
                                    t_width);
            break;
        case XtJustifyLeft:
        default:
            break;
        }

        y_loc += (entry->rectangle.height -
                (font_ascent + font_descent)) / 2 + font_ascent;

        XDrawString(XtDisplayOfObject(w), XtWindowOfObject(w), gc,
                x_loc, y_loc, label, len);
    }

    DrawBitmaps(w, gc);
}


/*      Function Name: SetValues
 *      Description: Relayout the menu when one of the resources is changed.
 *      Arguments: current - current state of the widget.
 *                 request - what was requested.
 *                 new - what the widget will become.
```

```
*     Returns: none
*/

/* ARGSUSED */
static Boolean
SetValues(current, request, new)
Widget current, request, new;
{
   SmeBSBprObject entry = (SmeBSBprObject) new;
   SmeBSBprObject old_entry = (SmeBSBprObject) current;
   Boolean ret_val = FALSE;

   if (old_entry->sme_bsb.label != entry->sme_bsb.label) {
      if (old_entry->sme_bsb.label != XtName( new ) )
         XtFree( (char *) old_entry->sme_bsb.label );

      if (entry->sme_bsb.label != XtName(new) )
         entry->sme_bsb.label = XtNewString( entry->sme_bsb.label );

      ret_val = True;
   }

   if (entry->rectangle.sensitive != old_entry->rectangle.sensitive )
      ret_val = TRUE;

   if (entry->sme_bsb.left_bitmap != old_entry->sme_bsb.left_bitmap) {
      GetBitmapInfo(new, TRUE);
      ret_val = TRUE;
   }

   if (entry->sme_bsb.right_bitmap != old_entry->sme_bsb.right_bitmap) {
      GetBitmapInfo(new, FALSE);
```

```
        ret_val = TRUE;
    }

    if ( (old_entry->sme_bsb.font != entry->sme_bsb.font) ||
         (old_entry->sme_bsb.foreground != entry->sme_bsb.foreground) ) {
        DestroyGCs(current);
        CreateGCs(new);
        ret_val = TRUE;
    }

    if (ret_val) {
        GetDefaultSize(new,
                       &(entry->rectangle.width), &(entry->rectangle.height));
        entry->sme_bsb.set_values_area_cleared = TRUE;
    }
    return(ret_val);
}

/*      Function Name: QueryGeometry.
 *      Description: Returns the preferred geometry for this widget.
 *      Arguments: w - the menu entry object.
 *                 itended, return_val - the intended and return geometry info.
 *      Returns: A Geometry Result.
 *
 * See the Intrinsics manual for details on what this function is for.
 *
 * I just return the height and width of the label plus the margins.
 */

static XtGeometryResult
QueryGeometry(w, intended, return_val)
Widget w;
```

```
XtWidgetGeometry *intended, *return_val;
{
   SmeBSBprObject entry = (SmeBSBprObject) w;
   Dimension width, height;
   XtGeometryResult ret_val = XtGeometryYes;
   XtGeometryMask mode = intended->request_mode;

   GetDefaultSize(w, &width, &height );

   if ( ((mode & CWWidth) && (intended->width != width)) ||
        !(mode & CWWidth) ) {
      return_val->request_mode |= CWWidth;
      return_val->width = width;
      ret_val = XtGeometryAlmost;
   }

   if ( ((mode & CWHeight) && (intended->height != height)) ||
        !(mode & CWHeight) ) {
      return_val->request_mode |= CWHeight;
      return_val->height = height;
      ret_val = XtGeometryAlmost;
   }

   if (ret_val == XtGeometryAlmost) {
      mode = return_val->request_mode;

      if ( ((mode & CWWidth) && (width == entry->rectangle.width)) &&
           ((mode & CWHeight) && (height == entry->rectangle.height)) )
         return(XtGeometryNo);
   }

   return(ret_val);
```

```
}

/*      Function Name: FlipColors
 *      Description: Invert the colors of the current entry.
 *      Arguments: w - the bsb menu entry widget.
 *      Returns: none.
 */

static void
FlipColors(w)
Widget w;
{
    SmeBSBprObject entry = (SmeBSBprObject) w;

    if (entry->sme_bsb.set_values_area_cleared) return;

    XFillRectangle(XtDisplayOfObject(w), XtWindowOfObject(w),
                   entry->sme_bsb.invert_gc, 0, (int) entry->rectangle.y,
                   (unsigned int) entry->rectangle.width,
                   (unsigned int) entry->rectangle.height);
}

/**************************************************************
 *
 * Private Functions.
 *
 **************************************************************/

/*      Function Name: GetDefaultSize
 *      Description: Calculates the Default (preferred) size of
 *                   this menu entry.
 *      Arguments: w - the menu entry widget.
```

```
*              width, height - default sizes (RETURNED).
*       Returns: none.
*/

static void
GetDefaultSize(w, width, height)
Widget w;
Dimension * width, * height;
{
    SmeBSBprObject entry = (SmeBSBprObject) w;

    if (entry->sme_bsb.label == NULL)
        *width = 0;
    else
        *width = XTextWidth(entry->sme_bsb.font, entry->sme_bsb.label,
                       strlen(entry->sme_bsb.label));

    *width += entry->sme_bsb.left_margin + entry->sme_bsb.right_margin;

    *height = (entry->sme_bsb.font->max_bounds.ascent +
            entry->sme_bsb.font->max_bounds.descent);

    *height = (*height * ( ONE_HUNDRED +
                       entry->sme_bsb.vert_space )) / ONE_HUNDRED;
}

/*      Function Name: DrawBitmaps
 *      Description: Draws left and right bitmaps.
 *      Arguments: w - the simple menu widget.
 *                 gc - graphics context to use for drawing.
 *      Returns: none
 */
```

```
static void
DrawBitmaps(w, gc)
Widget w;
GC gc;
{
   int x_loc, y_loc;
   SmeBSBprObject entry = (SmeBSBprObject) w;

   if ( (entry->sme_bsb.left_bitmap == None) &&
        (entry->sme_bsb.right_bitmap == None) ) return;

/*
 * Draw Left Bitmap.
 */

   y_loc = entry->rectangle.y + (entry->rectangle.height -
                         entry->sme_bsb.left_bitmap_height) / 2;

  if (entry->sme_bsb.left_bitmap != None) {
   x_loc = (entry->sme_bsb.left_margin -
           entry->sme_bsb.left_bitmap_width) / 2;
   XCopyPlane(XtDisplayOfObject(w), entry->sme_bsb.left_bitmap,
            XtWindowOfObject(w), gc, 0, 0,
            entry->sme_bsb.left_bitmap_width,
            entry->sme_bsb.left_bitmap_height, x_loc, y_loc, 1);
 }

/*
 * Draw Right Bitmap.
 */

   y_loc = entry->rectangle.y + (entry->rectangle.height - /* Xaw bug - y_loc
```

```
calculated from right_bitmap data */
                                entry->sme_bsb.right_bitmap_height) / 2;

  if (entry->sme_bsb.right_bitmap != None) {
    x_loc = entry->rectangle.width - (entry->sme_bsb.right_margin + /* Xaw bug - +
rather than - sign */
                                entry->sme_bsb.right_bitmap_width) / 2;
    XCopyPlane(XtDisplayOfObject(w), entry->sme_bsb.right_bitmap,
              XtWindowOfObject(w), gc, 0, 0,
              entry->sme_bsb.right_bitmap_width,
              entry->sme_bsb.right_bitmap_height, x_loc, y_loc, 1);
  }
}

/*      Function Name: GetBitmapInfo
 *      Description: Gets the bitmap information from either of the bitmaps.
 *      Arguments: w - the bsb menu entry widget.
 *                 is_left - TRUE if we are testing left bitmap,
 *                           FALSE if we are testing the right bitmap.
 *      Returns: none
 */

static void
GetBitmapInfo(w, is_left)
Widget w;
Boolean is_left;
{
    SmeBSBprObject entry = (SmeBSBprObject) w;
    unsigned int depth, bw;
    Window root;
    int x, y;
    unsigned int width, height;
```

```
char buf[BUFSIZ];

if (is_left) {
    if (entry->sme_bsb.left_bitmap != None) {
        if (!XGetGeometry(XtDisplayOfObject(w),
                    entry->sme_bsb.left_bitmap, &root,
                    &x, &y, &width, &height, &bw, &depth)) {
            sprintf(buf, "SmeBSB Object: %s %s \"%s\".", "Could not",
                "get Left Bitmap geometry information for menu entry ",
                XtName(w));
            XtAppError(XtWidgetToApplicationContext(w), buf);
        }
        if (depth != 1) {
            sprintf(buf, "SmeBSB Object: %s \"%s\"%s.",
                "Left Bitmap of entry ",
                XtName(w), " is not one bit deep.");
            XtAppError(XtWidgetToApplicationContext(w), buf);
        }
        entry->sme_bsb.left_bitmap_width = (Dimension) width;
        entry->sme_bsb.left_bitmap_height = (Dimension) height;
    }
}
else if (entry->sme_bsb.right_bitmap != None) {
    if (!XGetGeometry(XtDisplayOfObject(w),
                entry->sme_bsb.right_bitmap, &root,
                &x, &y, &width, &height, &bw, &depth)) {
        sprintf(buf, "SmeBSB Object: %s %s \"%s\".", "Could not",
            "get Right Bitmap geometry information for menu entry ",
            XtName(w));
        XtAppError(XtWidgetToApplicationContext(w), buf);
    }
    if (depth != 1) {
```

```
            sprintf(buf, "SmeBSB Object: %s \"%s\"%s.",
                    "Right Bitmap of entry ", XtName(w),
                    " is not one bit deep.");
            XtAppError(XtWidgetToApplicationContext(w), buf);
        }
        entry->sme_bsb.right_bitmap_width = (Dimension) width;
        entry->sme_bsb.right_bitmap_height = (Dimension) height;
    }
}

/*      Function Name: CreateGCs
 *      Description: Creates all gc's for the simple menu widget.
 *      Arguments: w - the simple menu widget.
 *      Returns: none.
 */

static void
CreateGCs(w)
Widget w;
{
    SmeBSBprObject entry = (SmeBSBprObject) w;
    XGCValues values;
    XtGCMask mask;

    values.foreground = XtParent(w)->core.background_pixel;
    values.background = entry->sme_bsb.foreground;
    values.font = entry->sme_bsb.font->fid;
    values.graphics_exposures = FALSE;
    mask        = GCForeground | GCBackground | GCFont | GCGraphicsExposures;
    entry->sme_bsb.rev_gc = XtGetGC(w, mask, &values);

    values.foreground = entry->sme_bsb.foreground;
```

```
values.background = XtParent(w)->core.background_pixel;
entry->sme_bsb.norm_gc = XtGetGC(w, mask, &values);

values.fill_style = FillTiled;
values.tile   = XmuCreateStippledPixmap(XtScreenOfObject(w),
                                        entry->sme_bsb.foreground,
                                        XtParent(w)->core.background_pixel,
                                        XtParent(w)->core.depth);
values.graphics_exposures = FALSE;
mask |= GCTile | GCFillStyle;
entry->sme_bsb.norm_gray_gc = XtGetGC(w, mask, &values);

values.foreground ^= values.background;
values.background = 0;
values.function = GXxor;
mask = GCForeground | GCBackground | GCGraphicsExposures | GCFunction;
entry->sme_bsb.invert_gc = XtGetGC(w, mask, &values);
}

/*    Function Name: DestroyGCs
 *    Description: Removes all gc's for the simple menu widget.
 *    Arguments: w - the simple menu widget.
 *    Returns: none.
 */

static void
DestroyGCs(w)
Widget w;
{
   SmeBSBprObject entry = (SmeBSBprObject) w;

   XtReleaseGC(w, entry->sme_bsb.norm_gc);
```

```
  XtReleaseGC(w, entry->sme_bsb.norm_gray_gc);
  XtReleaseGC(w, entry->sme_bsb.rev_gc);
  XtReleaseGC(w, entry->sme_bsb.invert_gc);
}

#ifdef apollo

/*
 * The apollo compiler that we have optomizes out my code for
 * FlipColors() since it is static. and no one executes it in this
 * file.  I am setting the function pointer into the class structure so
 * that it can be called by my parent who will tell me to when to
 * highlight and unhighlight.
 */

void _XawSmeBSBApolloHack ()
{
   FlipColors();
}
#endif /* apollo */

/* Hacked copy of PopupMenu from MenuButton widget to replace XtInheritNotify */

static void
PopupMenu(w, event, params, num_params)
Widget w;
XEvent * event;
String * params;
Cardinal * num_params;
{
  SmeBSBprObject mbw = (SmeBSBprObject) w;
  Widget menu, temp;
```

```
Arg arglist[2];
Cardinal num_args;
int menu_x, menu_y, menu_width, menu_height, button_width, button_height;
Position button_x, button_y;

temp = XtParent(w); /* Shell not menu entry is parent of menu */
while(temp != NULL) {
  menu = XtNameToWidget(temp, mbw->sme_bsb.menu_name);
  if (menu == NULL)
    temp = XtParent(temp);
  else
    break;
}

if (menu == NULL) {
  char error_buf[BUFSIZ];
  sprintf(error_buf, "MenuButton: %s %s.",
          "Could not find menu widget named", mbw->sme_bsb.menu_name);
  XtAppWarning(XtWidgetToApplicationContext(w), error_buf);
  return;
}
if (!XtIsRealized(menu))
  XtRealizeWidget(menu);

menu_width = menu->core.width + 2 * menu->core.border_width;
button_width = w->core.width + 2 * w->core.border_width;
button_height = w->core.height + 2 * w->core.border_width;

menu_height = menu->core.height + 2 * menu->core.border_width;

XtTranslateCoords(w, 0, 0, &button_x, &button_y);
menu_x = button_x + button_width;
```

```
menu_y = button_y;

if (menu_x < 0)
  menu_x = 0;
else {
  int scr_width = WidthOfScreen(XtScreen(menu));
  if (menu_x + menu_width > scr_width)
    menu_x = scr_width - menu_width;
}

if (menu_y < 0)
  menu_y = 0;
else {
  int scr_height = HeightOfScreen(XtScreen(menu));
  if (menu_y + menu_height > scr_height)
    menu_y = scr_height - menu_height;
}

num_args = 0;
XtSetArg(arglist[num_args], XtNx, menu_x); num_args++;
XtSetArg(arglist[num_args], XtNy, menu_y); num_args++;
XtSetValues(menu, arglist, num_args);

XtPopupSpringLoaded(menu);
}
```

source/Storage.c

```
/*
        Routines to allow video frames to be stored in memory
        or on disk: NewFrame, GetFrame, SaveFrame, FreeFrame, SaveHeader,
CopyHeader.
*/

#include        "../include/xwave.h"
extern FILE  *zropen();
extern void  zseek();
extern void  zclose();

void    NewFrame(vid,number)

Video vid;
int     number;

{
        if (vid->data[0][number]==NULL) {
                int     channel, channels=vid->type==MONO?1:3;

                for(channel=0;channel<channels;channel++)
                        vid->data[channel][number]=(short
*)MALLOC(sizeof(short)*Size(vid,channel,0)*Size(vid,channel,1));
        }
}

void    GetFrame(vid,number)

Video vid;
```

```
int     number;

{
        if (vid->data[0][number]==NULL) {
                char    file_name[STRLEN], *whole_frame;
                FILE    *fp, *fopen();
                int     pid, r, c, channel,
                                start=vid->x_offset+vid->cols*vid->y_offset,

end=(vid->rows-vid->y_offset-vid->size[1])*vid->cols-vid->x_offset,
                                inter=vid->cols-vid->size[0];

                NewFrame(vid,number);

sprintf(file_name,"%s%s/%s/%s%03d\0",global->home,IMAGE_DIR,vid->path,vid->f
iles[0]=='\0'?vid->name:vid->files,number+vid->start);
                Dprintf("Reading file %s\n",file_name);
                fp=zropen(file_name,&pid);
                if (vid->precision==0) whole_frame=(char
*)MALLOC(vid->rows*vid->cols);
                zseek(fp,vid->offset);
                for(channel=0;channel<(vid->type==MONO?1:3);channel++) {
                        int     shift[2]={vid->type==YUV &&
channel!=0?vid->UVsample[0]:0,vid->type==YUV &&
channel!=0?vid->UVsample[1]:0};

                        Dprintf("Reading channel %d\n",channel);
                        if (vid->precision==0) {

if(0==fread(whole_frame,sizeof(char),(vid->cols>>shift[0])*(vid->rows>>shift[1]),
fp)) {
                                        Dprintf("Error whilst reading %s\n",file_name);
```

```
                        Eprintf("Error whilst reading %s\n",file_name);
                }
                for(r=0;r<vid->size[1]>>shift[1];r++)
                        for(c=0;c<vid->size[0]>>shift[0];c++) {
                                short
pel=cti(whole_frame[(vid->x_offset>>shift[0])+c+((vid->y_offset>>shift[1])+r)*(
vid->cols>>shift[0])]);


vid->data[channel][number][c+r*(vid->size[0]>>shift[0])]=vid->negative?-1-pel:pel;
                }
        } else {
                if (start!=0) zseek(fp,start*sizeof(short));
                for(r=0;r<vid->size[1]>>shift[1];r++) {

if(0==fread(&(vid->data[channel][number][r*(vid->size[0]>>shift[0])]),sizeof(short),
vid->size[0]>>shift[0],fp)) {
                                Dprintf("Error whilst reading
%s\n",file_name);
                                Eprintf("Error whilst reading
%s\n",file_name);
                        }
                        if (inter!=0) zseek(fp,inter*sizeof(short));
                        if (vid->negative)
                                for(c=0;c<vid->size[0]>>shift[0];c++)

vid->data[channel][number][c+r*(vid->size[0]>>shift[0])]=-1-vid->data[channel][nu
mber][c+r*(vid->size[0]>>shift[0])];
```

source/Storage.c

```
/*
        Routines to allow video frames to be stored in memory
        or on disk: NewFrame, GetFrame, SaveFrame, FreeFrame, SaveHeader,
CopyHeader.
*/

#include        "../include/xwave.h"
extern FILE     *zropen();
extern void     zseek();
extern void     zclose();

void    NewFrame(vid,number)

Video   vid;
int     number;

{
        if (vid->data[0][number]==NULL) {
                int     channel, channels=vid->type==MONO?1:3;

                for(channel=0;channel<channels;channel++)
                        vid->data[channel][number]=(short
*)MALLOC(sizeof(short)*Size(vid,channel,0)*Size(vid,channel,1));
        }
}

void    GetFrame(vid,number)

Video   vid;
```

```
int     number;

{
        if (vid->data[0][number]==NULL) {
                char    file_name[STRLEN], *whole_frame;
                FILE    *fp, *fopen();
                int     pid, r, c, channel,
                                start=vid->x_offset+vid->cols*vid->y_offset,

end=(vid->rows-vid->y_offset-vid->size[1])*vid->cols-vid->x_offset,
                                inter=vid->cols-vid->size[0];

                NewFrame(vid,number);

sprintf(file_name,"%s%s/%s/%s%03d\0",global->home,IMAGE_DIR,vid->path,vid->f
iles[0]=='\0'?vid->name:vid->files,number+vid->start);
                Dprintf("Reading file %s\n",file_name);
                fp=zropen(file_name,&pid);
                if (vid->precision==0) whole_frame=(char
*)MALLOC(vid->rows*vid->cols);
                zseek(fp,vid->offset);
                for(channel=0;channel<(vid->type==MONO?1:3);channel++) {
                        int     shift[2]={vid->type==YUV &&
channel!=0?vid->UVsample[0]:0,vid->type==YUV &&
channel!=0?vid->UVsample[1]:0};

                        Dprintf("Reading channel %d\n",channel);
                        if (vid->precision==0) {

if(0==fread(whole_frame,sizeof(char),(vid->cols>>shift[0])*(vid->rows>>shift[1]),
fp)) {
                                        Dprintf("Error whilst reading %s\n",file_name);
```

```
                    Eprintf("Error whilst reading %s\n",file_name);
                }
                for(r=0;r<vid->size[1]>>shift[1];r++)
                    for(c=0;c<vid->size[0]>>shift[0];c++) {
                        short
pel=cti(whole_frame[(vid->x_offset>>shift[0])+c+((vid->y_offset>>shift[1])+r)*(
vid->cols>>shift[0])]);


vid->data[channel][number][c+r*(vid->size[0]>>shift[0])]=vid->negative?-1-pel:pel;
                    }
            } else {
                if (start!=0) zseek(fp,start*sizeof(short));
                for(r=0;r<vid->size[1]>>shift[1];r++) {

if(0==fread(&(vid->data[channel][number][r*(vid->size[0]>>shift[0])]),sizeof(short),
vid->size[0]>>shift[0],fp)) {
                            Dprintf("Error whilst reading
%s\n",file_name);
                            Eprintf("Error whilst reading
%s\n",file_name);
                    }
                    if (inter!=0) zseek(fp,inter*sizeof(short));
                    if (vid->negative)
                        for(c=0;c<vid->size[0]>>shift[0];c++)

vid->data[channel][number][c+r*(vid->size[0]>>shift[0])]=-1-vid->data[channel][nu
mber][c+r*(vid->size[0]>>shift[0])];
```

```
}


void    SaveHeader(vid)

Video vid;

{
        FILE   *fp, *fopen();
        char   file_name[STRLEN];
        String types[]={"MONO","RGB","YUV"};

        Dprintf("SaveHeader %s\n",vid->name);

sprintf(file_name,"%s%s/%s%s\0",global->home,VID_DIR,vid->name,VID_EXT);
        fp=fopen(file_name,"w");
        fprintf(fp,"Path \"%s\"\n",vid->path);
        if (vid->files[0]!='\0') fprintf(fp,"Files \"%s\"\n",vid->files);
        if (vid->type==YUV) fprintf(fp,"Type %s %d
%d\n",types[vid->type],vid->UVsample[0],vid->UVsample[1]);
        else fprintf(fp,"Type %s\n",types[vid->type]);
        if (vid->rate!=0) fprintf(fp,"Rate %d\n",vid->rate);
        if (vid->disk) fprintf(fp,"Disk\n");
        if (vid->gamma) fprintf(fp,"Gamma\n");
        fprintf(fp,"Start %03d\n",vid->start);
        fprintf(fp,"Length %d\n",vid->size[2]);
        fprintf(fp,"Dimensions %d %d\n",vid->cols,vid->rows);
        switch(vid->trans.type) {
        case   TRANS_None: fprintf(fp,"Transform None\n"); break;
        case   TRANS_Wave: fprintf(fp,"Transform Wavelet %d %d
 %s\n",vid->trans.wavelet.space[0],vid->trans.wavelet.space[1],vid->trans.wavelet.dirn
 ?"Yes":"No"); break;
```

```
        }
        fprintf(fp,"Header %d\n",vid->offset);
        fprintf(fp,"Offsets %d %d\n",vid->x_offset,vid->y_offset);
        fprintf(fp,"Size %d %d\n",vid->size[0],vid->size[1]);
        fprintf(fp,"Precision %d\n",vid->precision);
        fclose(fp);
}

Video CopyHeader(src)

Video src;

{
        Video dst=(Video)MALLOC(sizeof(VideoRec));
        int     channel;

        Dprintf("CopyHeader %s\n",src);
        strcpy(dst->path,src->path);
        strcpy(dst->name,src->name);
        dst->type=src->type;
        dst->disk=src->disk;
        dst->gamma=src->gamma;
        dst->negative=False;
        dst->rate=src->rate;
        dst->start=src->start;
        dst->size[0]=src->size[0];
        dst->size[1]=src->size[1];
        dst->size[2]=src->size[2];
        dst->UVsample[0]=src->UVsample[0];
        dst->UVsample[1]=src->UVsample[1];
        dst->offset=0;
        dst->cols=src->size[0];
```

```
        dst->rows=src->size[1];
        dst->x_offset=0;
        dst->y_offset=0;
        dst->trans=src->trans;
        dst->precision=src->precision;
        for(channel=0;channel<(src->type==MONO?1:3);channel++)
                dst->data[channel]=(short **)MALLOC(src->size[2]*sizeof(short *));
        return(dst);
}
```

source/Transform.c

```
/*
	Transform video using wavelet transform
*/

#include	"xwave.h"
#include	"Transform.h"
extern short	Round();

void	DropVideo(w,closure,call_data)

Widget		w;
caddr_t		closure, call_data;

{
	Video	video=global->videos->next;
	int	frame, channel;


for(channel=0;channel<(global->videos->type==MONO?1:(global->videos->type=
=YUV?3:4));channel++)
		if (global->videos->data[channel]!=NULL) {
			for (frame=0;frame<global->videos->size[2];frame++)
				if (global->videos->data[channel][frame]!=NULL)
XtFree(global->videos->data[channel][frame]);
			XtFree(global->videos->data[channel]);
		}
	XtFree(global->videos);
	global->videos=video;
```

```
}

void    ChangePrecision(src,dst,frame,old,new)

Video src, dst;
int     frame, old, new;

{
        int     channel, i;

        if(src!=dst || old!=new) {
                int     shift=new-old;

                Dprintf("Changing precision %d to %d for frame %d\n",old,new,frame);
                for (channel=0;channel<(src->type==MONO?1:3);channel++) {
                        int     size=Size(src,channel,0)*Size(src,channel,1);

                        for(i=0;i<size;i++)

dst->data[channel][frame][i]=shift<0?Round(src->data[channel][frame][i],-shift):(shift
==0?src->data[channel][frame][i]:src->data[channel][frame][i]<<shift);
                }
        }
}

void    TransformCtrl(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;

{
        TransCtrl       ctrl=(TransCtrl)closure;
```

```
Video src=ctrl->src, dst=CopyHeader(src);
long  i, frame, channel;

Dprintf("TransformCtrl\n");
strcpy(dst->name,ctrl->name);
dst->trans.type=TRANS_Wave;
dst->trans.wavelet.space[0]=ctrl->space[0];
dst->trans.wavelet.space[1]=ctrl->space[1];
dst->trans.wavelet.dirn=ctrl->dirn;
dst->precision=ctrl->precision;
strcpy(dst->files,dst->name);
if (dst->disk) SaveHeader(dst);
if (src->trans.type!=TRANS_Wave) {
        src->trans.type=TRANS_Wave;
        src->trans.wavelet.space[0]=0;
        src->trans.wavelet.space[1]=0;
}

if (src->trans.wavelet.space[0]!=dst->trans.wavelet.space[0] ||
src->trans.wavelet.space[1]!=dst->trans.wavelet.space[1])
        for(frame=0;frame<dst->size[2];frame++) {
                int
max_precision=src->precision>dst->precision?src->precision:dst->precision;

                Dprintf("Processing frame %d\n",frame);
                NewFrame(dst,frame);
                GetFrame(src,frame);
                ChangePrecision(src,dst,frame,src->precision,max_precision);
                for (channel=0;channel<(src->type==MONO?1:3);channel++)
{
                        int     oct_src=src->trans.wavelet.space[channel==0?0:1],
```

```
oct_dst=dst->trans.wavelet.space[channel==0?0:1],

size[2]={Size(dst,channel,0),Size(dst,channel,1)};

                        if (oct_src!=oct_dst)
Convolve(dst->data[channel][frame],ctrl->dirn,size,oct_src,oct_dst);
                    }
                    ChangePrecision(dst,dst,frame,max_precision,dst->precision);
                    SaveFrame(dst,frame);
                    FreeFrame(dst,frame);
                    FreeFrame(src,frame);
            }

        if (src->trans.wavelet.space[0]==0 && src->trans.wavelet.space[1]==0)
src->trans.type=TRANS_None;
        if (dst->trans.wavelet.space[0]==0 && dst->trans.wavelet.space[1]==0) {
                dst->trans.type=TRANS_None;
                if (dst->disk) SaveHeader(dst);
        }
        dst->next=global->videos;
        global->videos=dst;
}

void    Transtype(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        Video  vid=(Video)closure;

        if (vid->trans.wavelet.space[0]==0 && vid->trans.wavelet.space[1]==0)
```

```
vid->trans.type=TRANS_None;
}

void    BatchTransCtrl(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        TransCtrl       ctrl=(TransCtrl)closure;

        if (ctrl->src==NULL) ctrl->src=FindVideo(ctrl->src_name,global->videos);
        if (ctrl->src->trans.type==TRANS_Wave)
ctrl->dirn=ctrl->src->trans.wavelet.dirn;
        TransformCtrl(w,closure,call_data);
}

TransCtrl       InitTransCtrl(name)

String  name;

{
        TransCtrl       ctrl=(TransCtrl)MALLOC(sizeof(TransCtrlRec));

        strcpy(ctrl->src_name,name);
        strcpy(ctrl->name,name);
        ctrl->dirn=False;
        Dprintf("Transform\n");
        return(ctrl);
}

#define         TRANS_ICONS     16
```

```
void    Transform(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        Video  video=(Video)closure;
        TransCtrl      ctrl=InitTransCtrl(video->name);
        NumInput       spaceInput=(NumInput)MALLOC(2*sizeof(NumInputRec)),
                                precInput=(NumInput)MALLOC(sizeof(NumInputRec));
        Message        msg=NewMessage(ctrl->name,NAME_LEN);
        XtCallbackRec         destroy_call[]={
                {Free,(caddr_t)ctrl},
                {Free,(caddr_t)spaceInput},
                {Free,(caddr_t)precInput},
                {CloseMessage,(caddr_t)msg},
                {NULL,NULL},
        };
        Widget         parent=FindWidget("frm_transform",XtParent(w)),

shell=ShellWidget("transform",parent,SW_below,NULL,destroy_call),
                       form=FormatWidget("trans_form",shell),
widgets[TRANS_ICONS];
        FormItem       items[]={
                {"trans_cancel","cancel",0,0,FW_icon,NULL},
                {"trans_confirm","confirm",1,0,FW_icon,NULL},
                {"trans_title","Transform a video",2,0,FW_label,NULL},
                {"trans_vid_lab","Video Name:",0,3,FW_label,NULL},
                {"trans_video",NULL,4,3,FW_text,(String)msg},

                {"trans_dirn_lab","Direction:",0,4,FW_label,NULL},
                {"trans_dirn",NULL,4,4,FW_yn,(String)&ctrl->dirn},
```

```
        {"trans_bits_int",NULL,0,6,FW_integer,(String)precInput},
        {"trans_bits_down",NULL,4,6,FW_down,(String)precInput},
        {"trans_bits_up",NULL,9,6,FW_up,(String)precInput},

        {"trans_spc0_int",NULL,0,8,FW_integer,(String)&spaceInput[0]},
        {"trans_spc0_down",NULL,4,8,FW_down,(String)&spaceInput[0]},
        {"trans_spc0_up",NULL,12,8,FW_up,(String)&spaceInput[0]},
        {"trans_spc1_int",NULL,0,11,FW_integer,(String)&spaceInput[1]},
        {"trans_spc1_down",NULL,4,11,FW_down,(String)&spaceInput[1]},

        {"trans_spc1_up",NULL,15,11,FW_up,(String)&spaceInput[1]},
};
XtCallbackRec       callbacks[]={
        {Destroy,(caddr_t)shell},
        {NULL,NULL},
        {TransformCtrl,(caddr_t)ctrl},
        {Destroy,(caddr_t)shell},
        {NULL,NULL},
        {ChangeYN,(caddr_t)&ctrl->dirn}, {NULL,NULL},
        {NumIncDec,(caddr_t)precInput}, {NULL,NULL},
        {NumIncDec,(caddr_t)precInput}, {NULL,NULL},
        {NumIncDec,(caddr_t)&spaceInput[0]}, {NULL,NULL},
        {NumIncDec,(caddr_t)&spaceInput[0]}, {NULL,NULL},
        {NumIncDec,(caddr_t)&spaceInput[1]}, {NULL,NULL},
        {NumIncDec,(caddr_t)&spaceInput[1]}, {NULL,NULL},
};

Dprintf("Transform\n");
msg->rows=1; msg->cols=NAME_LEN;
ctrl->src=video;
if (video->trans.type==TRANS_Wave) {
        ctrl->space[0]=video->trans.wavelet.space[0];
```

```
            ctrl->space[1]=video->trans.wavelet.space[1];
            ctrl->dirn=video->trans.wavelet.dirn;
        } else {
            ctrl->space[0]=0; ctrl->space[1]=0;
            ctrl->dirn=False;
        }
        ctrl->precision=video->precision;

        spaceInput[0].format=video->type==YUV?"Y-Space: %d":"Space: %d";
        spaceInput[0].max=100;
        spaceInput[0].min=0;
        spaceInput[0].value=&ctrl->space[0];
        if (video->type==YUV) {
            spaceInput[1].format="UV-Space: %d";
            spaceInput[1].max=100;
            spaceInput[1].min=0;
            spaceInput[1].value=&ctrl->space[1];
        }
        precInput->format="Precision: %d";
        precInput->max=16;
        precInput->min=0;
        precInput->value=&ctrl->precision;


FillForm(form,TRANS_ICONS-(video->type==YUV?0:3),items,widgets,callbacks);
        if (video->trans.type==TRANS_Wave) XtSetSensitive(widgets[6],False);
        XtPopup(shell,XtGrabExclusive);
}
```

source/Update.c

```
/*
	Update Image, Info and InfoText from positional information
*/

#include	"../include/xwave.h"
#include	<varargs.h>
extern int	CompositePixel();
extern int	Dither();
extern short	Round();
extern int	ReMap();
extern Palette		FindPalette();

char	*ResizeData(size)

int	size;

{
	static char	*data=NULL;
	static int	data_size=0;

	if (size!=data_size) {
		Dprintf("New frame memory\n");
		if (data!=NULL) XtFree(data);
		data=(char *)MALLOC(size);
		data_size=size;
	}
	return(data);
}
```

```
Pixmap      UpdateImage(frame)

Frame frame;

{
        int     x, y, i;
        Display         *dpy=XtDisplay(global->toplevel);
        void    CvtIndex(), UpdatePoint();
        Palette         pal=FindPalette(global->palettes,frame->palette);
        Video   vid=frame->video;
        int     scrn=XDefaultScreen(dpy), depth=DisplayPlanes(dpy,scrn),
                        size[2]={Size(vid,frame->channel,0),Size(vid,frame->channel,1)},
                        img_size[2]={size[0]<<frame->zoom,size[1]<<frame->zoom},
                        bpl=(img_size[0]*depth+7)/8, new_size=img_size[1]*bpl,
                        space=vid->trans.wavelet.space[vid->type==YUV &&
frame->channel!=0 && frame->channel!=3?1:0];
        char    *data=ResizeData(new_size);
        XImage
*image=XCreateImage(dpy,global->visinfo->visual,depth,ZPixmap,0,data,img_size[0],i
mg_size[1],8,bpl);
        Pixmap
pixmap=XCreatePixmap(dpy,DefaultRootWindow(dpy),img_size[0],img_size[1],depth);

        Dprintf("UpdateImage\n");
        if (global->levels==2 && frame->channel==3) frame->channel=0;
        for(y=0;y<size[1];y++) for(x=0;x<size[0];x++) {
                int     data_x=x, data_y=y, off_x, off_y, oct;

                if (vid->trans.type==TRANS_Wave)
CvtIndex(x,y,size[0],size[1],space,&data_x,&data_y,&oct);
                for(off_x=0;off_x<1<<frame->zoom;off_x++)
                        for(off_y=0;off_y<1<<frame->zoom;off_y++) {
```

```
                        int     img_x=off_x+(x<<frame->zoom),
img_y=off_y+(y<<frame->zoom),

pix=CompositePixel(frame,data_x,data_y,img_x,img_y);



XPutPixel(image,img_x,img_y,ReMap(pix,global->levels,pal));
                }
        }

XPutImage(dpy,pixmap,DefaultGC(dpy,scrn),image,0,0,0,0,img_size[0],img_size[1]);
        if (frame->point_switch==True) UpdatePoint(dpy,frame,pixmap);
        XtFree(image);
        return(pixmap);
}

void    CvtIndex(x,y,max_x,max_y,oct,ret_x,ret_y,ret_oct)

int     x, y, max_x, max_y, oct, *ret_x, *ret_y, *ret_oct;

{
        Boolean         hgx=x>=(max_x>>1), hgy=y>=(max_y>>1);

        *ret_x=hgx?x-(max_x>>1):x;
        *ret_y=hgy?y-(max_y>>1):y;
        if (!hgx && !hgy && oct>1) {

 CvtIndex(*ret_x,*ret_y,max_x>>1,max_y>>1,oct-1,ret_x,ret_y,ret_oct);
                *ret_x= *ret_x<<1;
                *ret_y= *ret_y<<1;
                *ret_oct+=1;
        } else {
```

```
            *ret_x=(*ret_x<<1)+hgx;
            *ret_y=(*ret_y<<1)+hgy;
            *ret_oct=hgx || hgy?0:1;
        }
}

void   UpdateInfo(frame)

Frame frame;

{
        Message        msg=frame->msg;
        Video  vid=frame->video;
        int     *locn=frame->point->location, posn[2]={locn[0],locn[1]},
                        channel=3==frame->channel?0:frame->channel,
width=Size(vid,channel,0);
        short   *data=vid->data[channel][frame->frame];

        msg->info.ptr[0]='\0';
        msg->info.length=0;
        if (vid->type==YUV && channel!=0) {
                posn[0]=posn[0]>>vid->UVsample[0];
                posn[1]=posn[1]>>vid->UVsample[1];
        }
        if (vid->trans.type!=TRANS_Wave)
                Mprintf(msg,"Point   : x=%03d y=%03d t=%03d
c=%4d",locn[0],locn[1],frame->frame+vid->start,data[posn[0]+Size(vid,channel,0)*po
sn[1]]);
        else {
                int     octs=vid->trans.wavelet.space[vid->type==YUV &&
channel!=0?1:0],
                                X, Y, oct, sub,
```

```
blkDC[2]={(posn[0]>>octs)&-2,(posn[1]>>octs)&-2},
                              offDC[2]={(posn[0]>>octs)&1,(posn[1]>>octs)&1};


            Mprintf(msg,"Point   : f=%03d x=%03d
y=%03d\n",frame->frame+vid->start,locn[0],locn[1]);
            Mprintf(msg,"Low pass: x=%03d y=%03d\n",blkDC[0],blkDC[1]);
            for(Y=0;Y<2;Y++) {
                  for(X=0;X<2;X++)

Mprintf(msg,"%4d%c",data[Access(blkDC[0]+X,blkDC[1]+Y,octs-1,0,width)],X==off
DC[0] && Y==offDC[1]?'*':' ');
                  Mprintf(msg,"\n");
            }
            for(oct=octs;oct>0;oct--) {
                  int     blk[2]={(posn[0]>>oct)&-2,(posn[1]>>oct)&-2},
                                off[2]={(posn[0]>>oct)&1,(posn[1]>>oct)&1};

                  Mprintf(msg,"Oct : %d\n",oct);
                  for(Y=0;Y<2;Y++) {
                        for(sub=1;sub<4;sub++) {
                              for(X=0;X<2;X++) {

Mprintf(msg,"%4d%c",data[Access(blk[0]+X,blk[1]+Y,oct-1,sub,width)],X==off[0]
&& Y==off[1]?'*':' ');
                              }
                              if (sub<3) Mprintf(msg,"   ");
                        }
                        if (oct!=0 || Y==0) Mprintf(msg,"\n");
                  }
            }
      }
```

```
    Mflush(msg);
}

/*    Function Name:    CrossHair.
 *    Description:  Draws cross-hair on pixmap
 *    Arguments:    dpy - Xserver display
 *                  pixmap - pixmap to draw on
 *                  gc - GC to draw with
 *                  x_off, y_off - offset into pixmap
 *                  width, height - size of box containing cross-hair
 *                  x, y - coordinates within box
 *                  zoom - scaling factor
 *    Returns:      alters pixmap.
 */

void  CrossHair(dpy,pixmap,gc,x_off,y_off,width,height,x,y,zoom)

Display     *dpy;
Pixmap      pixmap;
GC          gc;
int   x_off, y_off, width, height, x, y, zoom;

{
    int   xtra=Shift(1,zoom);

    x_off=Shift(x_off,zoom);
    y_off=Shift(y_off,zoom);
    width=Shift(width,zoom);
    height=Shift(height,zoom);
    x=Shift(x,zoom);
    y=Shift(y,zoom);
```

```
	XFillRectangle(dpy,pixmap,gc,x+x_off+xtra/2,y_off,1,y); /* North hair */
	XFillRectangle(dpy,pixmap,gc,x_off,y+y_off+xtra/2,x,1); /* West hair */
	XFillRectangle(dpy,pixmap,gc,x+x_off+xtra/2,y+y_off+xtra,1,height-y-xtra); /*
South hair */
	XFillRectangle(dpy,pixmap,gc,x+x_off+xtra,y+y_off+xtra/2,width-x-1,1); /*
East hair */
}

/*	Function Name:	UpdatePoint
 *	Description:	Draws cross-hair on image at frame->location
 *	Arguments:	dpy - X server display
 *			frame - Frame supplying drawing parameters
 *			pixmap - X pixmap to draw on
 *	Returns:	alters pixmap.
 */

void	UpdatePoint(dpy,frame,pixmap)

Display	*dpy;
Frame frame;
Pixmap	pixmap;

{
	unsigned long	gcmask;
	XGCValues	gcvals;
	GC	gc;
	Video	vid=frame->video;
	int	posn[2]={frame->point->location[0],frame->point->location[1]},
channel=3==frame->channel?0:frame->channel;

	gcvals.function=GXequiv;
	gcmask=GCFunction;
```

```
gcvals.foreground=127;
gcmask=gcmask||GCForeground;
gc=XCreateGC(dpy,pixmap,gcmask,&gcvals);
if (vid->type==YUV && channel!=0) {
        posn[0]=posn[0]>>vid->UVsample[0];
        posn[1]=posn[1]>>vid->UVsample[1];
}
if (vid->trans.type!=TRANS_Wave) {

CrossHair(dpy,pixmap,gc,0,0,Size(vid,channel,0),Size(vid,channel,1),posn[0],posn[1],fra
me->zoom);
} else {
        int     octs=vid->trans.wavelet.space[vid->type==YUV &&
channel!=0?1:0], oct,
                size[2]={Size(vid,channel,0),Size(vid,channel,1)};


CrossHair(dpy,pixmap,gc,0,0,size[0],size[1],posn[0],posn[1],frame->zoom-octs);
        for(oct=1;oct<=octs;oct++) {

CrossHair(dpy,pixmap,gc,size[0],0,size[0],size[1],posn[0],posn[1],frame->zoom-oct);

CrossHair(dpy,pixmap,gc,0,size[1],size[0],size[1],posn[0],posn[1],frame->zoom-oct);

CrossHair(dpy,pixmap,gc,size[0],size[1],size[0],size[1],posn[0],posn[1],frame->zoom-oct
);
        }
}
XFreeGC(dpy,gc);
}
```

source/Video2.c

```
/*
	Video callback routines for Listing, Loading
*/

#include	"../include/xwave.h"
#include	"../include/ImageHeader.h"
#include	"../include/DTheader.h"
#include	"Video.h"
#include	<sys/time.h>
extern void	EraseFrame();
extern void	CvtIndex();

void	SortList(list,no)

String	list[];
int	no;

{
	int	i, j, k;

	if (no>1) for(i=1;i<no;i++) for(j=0;j<i;j++) {
		k=0;
		while(list[i][k]==list[j][k] && list[i][k]!='\0' && list[j][k]!='\0') k++;
		if (list[i][k]<list[j][k]) {
			String	spare=list[i];

			list[i]=list[j];
			list[j]=spare;
		}
```

```
        }
}

String *ReadDirectory(dir_path,extension)

String dir_path, extension;

{
        DIR     *dirp, *opendir();
        struct  dirent  *dp, *readdir();
        static  String  *fileList=NULL, file;
        int     count=0, i;
        char    path[STRLEN];

        Dprintf("ReadDirectory for %s extension\n",extension);
        if (fileList!=NULL) {
                for(i=0;NULL!=fileList[i];i++) free(fileList[i]);
                free(fileList);
        }
        fileList=(String *)MALLOC(sizeof(String *)*300);
        sprintf(path,"%s%s\0",global->home,dir_path);
        dirp=opendir(path);
        for (dp=readdir(dirp);dp!=NULL && count<299;dp=readdir(dirp)) {
                int     length=strlen(dp->d_name);

                if (length>=strlen(extension))
                if (!strcmp(dp->d_name+length-strlen(extension),extension)) {
                        Dprintf("Found %s in dir\n",dp->d_name);
                        fileList[count]=(char *)MALLOC(length+1);
                        strncpy(fileList[count],dp->d_name,length-strlen(extension));
                        count+=1;
                }
```

```
        }
        fileList[count]=NULL;
        SortList(fileList,count);
        closedir(dirp);
        return(fileList);
}

int     Shift(value,shift)

int     value, shift;

{
        if (shift==0) return value;
        else if (shift<0) return(value>>-shift);
        else return(value<<shift);
}

int     Size(video,channel,dimension)

Video   video;
int     channel, dimension;

{
        if (video->type==YUV && dimension!=2 && channel!=0 && channel!=3)
return(video->size[dimension]>>video->UVsample[dimension]);
        else return(video->size[dimension]);
}

int     Address2(video,channel,x,y)

Video   video;
int     channel, x, y;
```

```
{
        if (video->type==YUV && channel!=0 && channel!=3)
return(x+Size(video,channel,0)*y);
        else return(x+video->size[0]*y);
}

int     Address(video,channel,x,y)

Video   video;
int     channel, x, y;

{
        if (video->type==YUV && channel!=0 && channel!=3)
return((x>>video->UVsample[0])+Size(video,channel,0)*(y>>video->UVsample[1])
);
        else return(x+video->size[0]*y);
}

String  *VideoList()

{
        Dprintf("VideoList\n");
        return(ReadDirectory(VID_DIR,VID_EXT));
}

String  *KlicsList()

{
        Dprintf("KlicsList\n");
        return(ReadDirectory(KLICS_DIR,KLICS_EXT));
}
```

```
String *KlicsListSA()

{
	Dprintf("KlicsListSA\n");
	return(ReadDirectory(KLICS_SA_DIR,KLICS_SA_EXT));
}

String *VideoCurrentList()

{
	static String videoList[300];
	Video video=global->videos;
	int count=0;

	Dprintf("VideoCurrentList\n");
	while (video!=NULL) {
		if (count==300) Dprintf("VideoCurrentList: static size exceeded\n");
		videoList[count]=video->name;
		video=video->next;
		count+=1;
	}
	videoList[count]=NULL;
	SortList(videoList,count);
	return(videoList);
}

String *VideoYUVList()

{
	static String videoList[300];
	Video video=global->videos;
	int count=0;
```

```
	Dprintf("VideoCurrentList\n");
	while (video!=NULL) {
		if (count==300) Dprintf("VideoYUVList: static size exceeded\n");
		if (video->type==YUV) videoList[count++]=video->name;
		video=video->next;
	}
	videoList[count]=NULL;
	SortList(videoList,count);
	return(videoList);
}

String *VideoDropList()

{
	static String videoList[300];
	Video video=global->videos;
	int count=0;
	Boolean VideoHasFrame();

	Dprintf("VideoDropList\n");
	while (video!=NULL) {
		if (False==VideoHasFrame(video,global->frames)) {
			videoList[count]=video->name;
			count+=1;
		};
		video=video->next;
	}
	videoList[count]=NULL;
	SortList(videoList,count);
	return(videoList);
}
```

```
Boolean      VideoHasFrame(video,frame)

Video video;
Frame frame;

{
        if (frame==NULL) return(False);
        else if (frame->video==video) return(True);
                else return(VideoHasFrame(video,frame->next));
}

void   VideoLoad(w,closure,call_data)

Widget        w;
caddr_t       closure, call_data;

{
        Video vid=(Video)MALLOC(sizeof(VideoRec));
        XawListReturnStruct *name=(XawListReturnStruct *)call_data;
        int     frame, channel;

        Dprintf("VideoLoad %s\n",name->string);
        strcpy(vid->name,name->string);
        strcpy(vid->files,name->string);
        vid->next=global->videos;
        global->videos=vid;
        vid->rate=30;
        Parse(VID_DIR,name->string,VID_EXT);
        for (channel=0;channel<(vid->type==MONO?1:3);channel++)
                vid->data[channel]=(short **)MALLOC(sizeof(short *)*vid->size[2]);
        if (!vid->disk) for(frame=0;frame<vid->size[2];frame++)
GetFrame(vid,frame);
```

```
	Dprintf("VideoLoad terminated\n");
	if (global->batch==NULL) InitFrame(w,closure,call_data);
}

void	VideoSave(w,closure,call_data)

Widget		w;
caddr_t		closure, call_data;

{
	Video	video;
	XawListReturnStruct *name=(XawListReturnStruct *)call_data;
	int	frame;

	video=FindVideo(name->string,global->videos);
	if (video->files[0]=='\0') strcpy(video->files,name->string);
	SaveHeader(video);
	for (frame=0;frame<video->size[2];frame++) {
		Boolean		disk=video->disk;

		GetFrame(video,frame);
		video->disk=True;
		SaveFrame(video,frame);
		video->disk=disk;
		FreeFrame(video,frame);
	}
	Dprintf("VideoSave terminated\n");
}

void	VideoDTSave(w,closure,call_data)

Widget		w;
```

```
caddr_t         closure, call_data;

{
        Video  video;
        FILE   *fp, *fopen();
        XawListReturnStruct *name=(XawListReturnStruct *)call_data;
        char   file_name[STRLEN], whole_frame[512][512];
        int    frame, i, x, y, offset[2];
        DTheader
header={"DT-IMAGE",1,4,1,2,"","",1,{0,0,4,0},1,1,0,1,{4,3},8,1,{0,2},{0,2},{0,2},{0
,2},"","xwave generated image",""};

        Dprintf("VideoDTSave %s\n",name->string);
        video=FindVideo(name->string,global->videos);

sprintf(file_name,"%s%s/%s/%s%s\0",global->home,IMAGE_DIR,video->path,video-
>files,".img");
        offset[0]=(512-video->size[0])/2;
        offset[1]=(512-video->size[1])/2;
        offset[0]=offset[0]<0?0:offset[0];
        offset[1]=offset[1]<0?0:offset[1];
        fp=fopen(file_name,"w");
        fwrite(&header,1,sizeof(DTheader),fp);
        GetFrame(video,0);
        for(y=0;y<512;y++) for(x=0;x<512;x++) {
                int     X, Y, oct;

                if (y<offset[1] || x<offset[0] || y-offset[1]>=video->size[1] ||
x-offset[0]>=video->size[0]) whole_frame[y][x]=0;
                else {
                        if (video->trans.type==TRANS_Wave) {
```

```
CvtIndex(x-offset[0],y-offset[1],video->size[0],video->size[1],video->trans.wavelet.spa
ce[0],&X,&Y,&oct);

whole_frame[y][x]=128+Round(video->data[0][0][Y*video->size[0]+X]*(oct==video
->trans.wavelet.space[0]?1:4),video->precision);
                    } else {
                        X=x-offset[0]; Y=y-offset[1];

whole_frame[y][x]=128+Round(video->data[0][0][Y*video->size[0]+X],video->preci
sion);
                    }
                }
        }
        FreeFrame(video,0);
        fwrite(whole_frame,1,512*512,fp);
        fclose(fp);
}

void    VideoXimSave(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        Video video;
        FILE  *fp, *fopen();
        XawListReturnStruct *name=(XawListReturnStruct *)call_data;
        char    file_name[STRLEN], *whole_frame;
        int     frame, channel, i, x, y;
        ImageHeader header;

        Dprintf("VideoXimSave %s\n",name->string);
```

```
        video=FindVideo(name->string,global->videos);
        whole_frame=(char *)MALLOC(video->size[0]*video->size[1]);
        if (video->files[0]=='\0') strcpy(video->files,name->string);

sprintf(file_name,"%s%s/%s/%s%s\0",global->home,IMAGE_DIR,video->path,video-
>files,".xim");
        fp=fopen(file_name,"w");
        sprintf(header.file_version,"%8d",IMAGE_VERSION);
        sprintf(header.header_size,"%8d",1024);
        sprintf(header.image_width,"%8d",video->size[0]);
        sprintf(header.image_height,"%8d",video->size[1]);
        sprintf(header.num_colors,"%8d",256);
        sprintf(header.num_channels,"%8d",video->type==MONO?1:3);
        sprintf(header.num_pictures,"%8d",video->size[2]);
        sprintf(header.alpha_channel,"%4d",0);
        sprintf(header.runlength,"%4d",0);
        sprintf(header.author,"%48s","xwave");
        sprintf(header.date,"%32s","Now");
        sprintf(header.program,"%16s","xwave");
        for(i=0;i<256;i++) {
                header.c_map[i][0]=(unsigned char)i;
                header.c_map[i][1]=(unsigned char)i;
                header.c_map[i][2]=(unsigned char)i;
        }
        fwrite(&header,1,sizeof(ImageHeader),fp);
        for (frame=video->start;frame<video->start+video->size[2];frame++) {
                GetFrame(video,frame-video->start);
                for(channel=0;channel<(video->type==MONO?1:3);channel++) {
                        for(x=0;x<video->size[0];x++)
                                for(y=0;y<video->size[1];y++)

whole_frame[x+video->size[0]*y]=itc(video->data[channel][frame-video->start][Addre
```

```
ss(video,channel,x,y)] >> video->precision);
                        fwrite(whole_frame,sizeof(char),video->size[0]*video->size[1],fp);
                }
                FreeFrame(video,frame-video->start);
        }
        fclose(fp);
        XtFree(whole_frame);
}

void    VideoMacSave(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;

{
        Video   video;
        FILE    *fp, *fopen();
        XawListReturnStruct *name=(XawListReturnStruct *)call_data;
        char    file_name[STRLEN], *whole_frame;
        int     frame, channel, i, x, y;

        Dprintf("VideoMacSave %s\n",name->string);
        video=FindVideo(name->string,global->videos);
        if (video->files[0]=='\0') strcpy(video->files,name->string);

sprintf(file_name,"%s%s/%s/%s%s\0",global->home,IMAGE_DIR,video->path,video-
>files,".mac");
        fp=fopen(file_name,"w");
        whole_frame=(char *)MALLOC(video->size[1]*video->size[0]*3);
        for(frame=0;frame<video->size[2];frame++) {
                int     size=video->size[0]*video->size[1];
```

```
            GetFrame(video,frame);
            for(channel=0;channel<(video->type==MONO?1:3);channel++)
                  for(x=0;x<video->size[0];x++)
                        for(y=0;y<video->size[1];y++)

whole_frame[(x+video->size[0]*y)*3+channel]=itc(video->data[channel][frame][Addre
ss(video,channel,x,y)]>>video->precision);
            fwrite(whole_frame,1,3*size,fp);
            FreeFrame(video,frame);
      }
      fclose(fp);
      XtFree(whole_frame);
}

void   VideoHexSave(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
      Video  video;
      FILE   *fp, *fopen();
      XawListReturnStruct *name=(XawListReturnStruct *)call_data;
      char   file_name[STRLEN];
      int    frame, channel, i;

      Dprintf("VideoHexSave %s\n",name->string);
      video=FindVideo(name->string,global->videos);
      if (video->files[0]=='\0') strcpy(video->files,name->string);

sprintf(file_name,"%s%s/%s/%s%s\0",global->home,IMAGE_DIR,video->path,video-
>files,".h");
```

```
	fp=fopen(file_name,"w");
	for(frame=0;frame<(video->size[2]>2?2:video->size[2]);frame++) {
			int	size=video->size[1]*video->size[0];

			GetFrame(video,frame);
			fprintf(fp,"char
%s%d[%d]={\n",name->string[strlen(name->string)-1]=='d'?"src":"dst",frame,size);
			for(i=0;i<size;i++)

fprintf(fp,"0x%02x,%c",(video->data[0][frame][i]>>video->precision)+128,i%20==
19?'\n':' ');
			fprintf(fp,"\n};\n");
			FreeFrame(video,frame);
	}
	fclose(fp);
}

#define AB_WIDTH 1440
#define AB_HEIGHT 486

void	VideoAbekusSave(w,closure,call_data)

Widget		w;
caddr_t		closure, call_data;

{
	AbekusCtrl	ctrl=(AbekusCtrl)closure;
	FILE	*fp, *fopen();
	char	file_name[STRLEN], *data=(char
*)MALLOC(AB_WIDTH*AB_HEIGHT), zero=itc(0);
	int	frame, channel, i, x, y, length=0;
	Video	vids[4];
```

```
Dprintf("VideoAbekusSave\n");
for(i=0;i<4;i++)
        if (ctrl->names[i]!=NULL) {
                vids[i]=FindVideo(ctrl->names[i],global->videos);
                length=length>vids[i]->size[2]?length:vids[i]->size[2];
        } else vids[i]=NULL;
for(frame=0;frame<length;frame++) {
        sprintf(file_name,"%d.yuv\0",frame+1);
        fp=fopen(file_name,"w");
        for(i=0;i<4;i++) GetFrame(vids[i],frame);
        for(y=0;y<AB_HEIGHT;y++)
                for(x=0;x<AB_WIDTH;x++) {
                        int
i=(x<AB_WIDTH/2?0:1)+(y<AB_HEIGHT/2?0:2),
                                Y=y<AB_HEIGHT/2?y:y-AB_HEIGHT/2,
                                X=(x<AB_WIDTH/2?x:x-AB_WIDTH/2)/2,
                                channel=((x&1)==1)?0:((X&1)==0)?1:2;

                        if (vids[i]->type==MONO && channel!=0 ||
X>=vids[i]->size[0] || Y>=vids[i]->size[1]) data[x+y*AB_WIDTH]=zero;
                        else
data[x+y*AB_WIDTH]=itc(vids[i]->data[channel][frame][Address(vids[i],channel,X,Y)]
>>vids[i]->precision);
                }
        for(i=0;i<4;i++) {
                FreeFrame(vids[i],frame);
                EraseFrame(vids[i],frame);
        }
        fwrite(data,1,AB_WIDTH*AB_HEIGHT,fp);
        fclose(fp);
    }
}
```

```
void    VideoDrop(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;

{
        Video  *videos=&global->videos, video;
        XawListReturnStruct *name=(XawListReturnStruct *)call_data;
        int     channel, frame;

        Dprintf("VideoDrop %s\n",name->string);
        video=FindVideo(name->string,global->videos);
        while (*videos!=video && *videos!=NULL) videos=&((*videos)->next);
        if (*videos!=NULL) {
                *videos=(*videos)->next;
                for(channel=0;channel<(video->type==MONO?1:3);channel++)
                        if (video->data[channel]!=NULL) {
                                for(frame=0;frame<video->size[2];frame++)
                                        if (video->data[channel][frame]!=NULL)
XtFree(video->data[channel][frame]);
                                XtFree(video->data[channel]);
                        }
                XtFree(video);
        }
}
/* Obsolete
void    VideoDiff(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;

{
```

```
	XawListReturnStruct *name=(XawListReturnStruct *)call_data;
	Video	src=FindVideo(name->string,global->videos), dst=CopyHeader(src);
	int	frame, channel, i;

	printf("VideoDiff %s\n",name->string);
	sprintf(dst->name,"%s.dif\0",src->name);
	for(frame=0;frame<src->size[2];frame++) {
		GetFrame(src,frame);
		NewFrame(dst,frame);
		for(channel=0;channel<(video->type==MONO?1:3);channel++)
			for(i=0;i<src->size[1]*src->size[0];i++)

dst->data[channel][frame][i]=src->data[channel][frame][i])-(frame==0?0:src->data[ch
annel][frame-1][i]);
		SaveFrame(dst,frame);
		FreeFrame(dst,frame);
		if (frame>0) FreeFrame(src,frame-1);
	}
	FreeFrame(dst,src->size[2]-1);
	dst->next=global->videos;
	global->videos=dst;
}
*/
void	VideoClean(w,closure,call_data)

Widget	w;
caddr_t	closure, call_data;

{
	Video	*videos=&global->videos, video;
	int	channel, frame;
```

```
	Dprintf("VideoClean\n");
	while(*videos!=NULL) {
		video=*videos;
		if (False==VideoHasFrame(video,global->frames)) {
			Dprintf("Erasing video: %s\n",video->name);

for(channel=0;channel<(video->type==MONO?1:3);channel++)
					if (video->data[channel]!=NULL) {
						for(frame=0;frame<video->size[2];frame++)
							if (video->data[channel][frame]!=NULL)
XtFree(video->data[channel][frame]);
						XtFree(video->data[channel]);
					}
			*videos=video->next;
			XtFree(video);
		} else videos=&(*videos)->next;
	}
}

typedef		struct {
	Frame frame;
	XtIntervalId	id;
	unsigned long		interval;
	long	msec, shown, average;
	Pixmap		*movie;
	int	fno, old_fno;
} MovieArgRec, *MovieArg;

void	Projector(client_data,id)

XtPointer	client_data;
XtIntervalId	*id;
```

```
{
        MovieArg     movieArg=(MovieArg)client_data;
        Display      *dpy=XtDisplay(global->toplevel);
        struct  timeval       tp;
        struct  timezone      tzp;
        long    new_msec;
        int     scrn=XDefaultScreen(dpy);


movieArg->id=XtAppAddTimeOut(global->app_con,movieArg->interval,Projector,mo
vieArg);
        gettimeofday(&tp,&tzp);
        new_msec=tp.tv_sec*1000+tp.tv_usec/1000;
        if (movieArg->msec!=0) {

movieArg->average=(movieArg->average*movieArg->shown+new_msec-movieArg-
>msec)/(movieArg->shown+1);
                movieArg->shown++;
        }
        movieArg->msec=new_msec;

XCopyArea(dpy,movieArg->movie[movieArg->fno],XtWindow(movieArg->frame->i
mage_widget),DefaultGC(dpy,scrn),0,0,movieArg->frame->video->size[0],movieArg-
>frame->video->size[1],0,0);

movieArg->fno=movieArg->fno==movieArg->frame->video->size[2]-1?0:movieAr
g->fno+1;
}

void    StopMovie(w,closure,call_data)

Widget          w;
```

```
caddr_t       closure, call_data;

{
        MovieArg      movieArg=(MovieArg)closure;
        Display       *dpy=XtDisplay(global->toplevel);
        int     i;
        Arg     args[1];

        XtRemoveTimeOut(movieArg->id);
        Dprintf("Movie showed %d frames at an average of %f
fps\n",movieArg->shown,1000.0/(float)movieArg->average);
        for(i=0;i<movieArg->frame->video->size[2];i++)
XFreePixmap(dpy,movieArg->movie[i]);
        XtFree(movieArg->movie);
        XtSetArg(args[0],XtNbitmap,UpdateImage(movieArg->frame));
        XtSetValues(movieArg->frame->image_widget,args,ONE);
        XSynchronize(dpy,False);
}

#define       MOVIE_ICONS     1

void  Movie(w,closure,call_data)

Widget        w;
caddr_t       closure, call_data;

{
        Video  video=((Frame)closure)->video;
        MovieArg      movieArg=(MovieArg)MALLOC(sizeof(MovieArgRec));
        Widget        shell=ShellWidget("movie",XtParent(w),SW_over,NULL,NULL),
                      form=FormatWidget("movie_form",shell),
widgets[MOVIE_ICONS];
```

```
Display        *dpy=XtDisplay(globai->toplevel);
FormItem       items[]={
        {"movie_stop","stop",0,0,FW_icon,NULL},
};
XtCallbackRec         callbacks[]={
        {StopMovie,(caddr_t)movieArg},
        {Free,(caddr_t)movieArg},
        {Destroy,(caddr_t)shell},
        {NULL,NULL},
};
int     i;
XGCValues    values;
GC      gc;

Dprintf("Movie\n");

FillForm(form,MOVIE_ICONS,items,widgets,callbacks);
XtPopup(shell,XtGrabExclusive);

values.foreground=255;
values.background=0;
gc=XtGetGC(XtParent(w),GCForeground | GCBackground,&values);
movieArg->frame=(Frame)closure;
movieArg->movie=(Pixmap *)MALLOC(video->size[2]*sizeof(Pixmap));
movieArg->old_fno=movieArg->frame->frame;
for(i=0;i<video->size[2];i++) {
        char    fno[STRLEN];

        sprintf(fno,"%03d\0",i+video->start);
        movieArg->frame->frame=i;
        GetFrame(video,i);
        movieArg->movie[i]=UpdateImage(movieArg->frame);
```

```
XDrawImageString(dpy,movieArg->movie[i],gc,video->size[0]-50,10,fno,3);

XCopyArea(dpy,movieArg->movie[i],XtWindow(movieArg->frame->image_widget),D
efaultGC(dpy,0),0,0,video->size[0],video->size[1],0,0);
            movieArg->frame->frame=movieArg->old_fno;
            FreeFrame(video,i);
        }
        XtDestroyGC(gc);
        movieArg->fno=0;
        movieArg->msec=0;
        movieArg->shown=0;
        movieArg->average=0;
        movieArg->interval=1000/video->rate;

movieArg->id=XtAppAddTimeOut(global->app_con,movieArg->interval,Projector,mo
vieArg);
        XSynchronize(dpy,True);
}

void    Compare(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
        XawListReturnStruct *name=(XawListReturnStruct *)call_data;
        Video   src=(Video)closure, dst=FindVideo(name->string,global->videos);
        int     channels=src->type==MONO || dst->type==MONO?1:3, channel,
values=0, x, y,
                frames=src->size[2]>dst->size[2]?dst->size[2]:src->size[2],
frame;
```

```
	double		mse;
	Message		msg=NewMessage(NULL,400);
	XtCallbackRec		callbacks[]={
		{CloseMessage,(caddr_t)msg}, {NULL,NULL},
	};

	msg->rows=frames>5?10:2*frames; msg->cols=40;
	if (global->batch==NULL)
MessageWindow(FindWidget("frm_compare",w),msg,"Compare",True,callbacks);
	for(frame=0;frame<frames;frame++) {
		Boolean		srcp=src->precision>dst->precision;
		int	err_sqr=0,
precision=srcp?src->precision-dst->precision:dst->precision-src->precision;

		Mprintf(msg,"Compare: %s%03d and
%s%03d\n",src->name,src->start+frame,dst->name,dst->start+frame);
		GetFrame(src,frame);
		GetFrame(dst,frame);
		for(channel=0;channel<channels;channel++) {

values+=Size(src->size[1]>dst->size[1]?dst:src,channel,1)*Size(src->size[0]>dst->s
ize[0]?dst:src,channel,0);

for(y=0;y<Size(src->size[1]>dst->size[1]?dst:src,channel,1);y++)

for(x=0;x<Size(src->size[0]>dst->size[0]?dst:src,channel,0);x++) {
					int
err=(src->data[channel][frame][x+Size(src,channel,0)*y]<<(srcp?0:precision))-(dst->
data[channel][frame][x+Size(dst,channel,0)*y]<<(srcp?precision:0));

					err_sqr+=err*err;
				}
```

```
        }
        FreeFrame(src,frame);
        FreeFrame(dst,frame);
        mse=(double)err_sqr/(double)(values);
        Mprintf(msg,"Error %d MSE %f PSNR
%f\n",err_sqr,mse,10*log10(pow((pow(2.0,(double)(8+(srcp?src->precision:dst->precis
ion)))-1),2.0)/mse));
        Mflush(msg);
    }
}

void    BatchCompare(w,closure,call_data)

Widget      w;
caddr_t     closure, call_data;

{
    String  name=(String)closure;

    closure=(caddr_t)FindVideo(name,global->videos);
    Compare(w,closure,call_data);
}
```

source/xwave.c

```
#include    "../include/xwave.h"
#include    <X11/Xresource.h>
#include    <X11/Intrinsic.h>
#include    <X11/Quarks.h>

extern Palette      ReOrderPalettes();
extern void   NameButton();
extern void   ImageNotify();
extern void   Parse();

#define    IconPath      "bitmaps"
#define    IconFile      "xwave.icons"
#define    CompressPath       "."
#define    CompressExt  ".compress"
#define    PalettePath   "."
#define    PaletteExt    ".pal"

Global     global;

String ChannelName[3][4]={
    {"GreyScale",NULL,NULL,NULL},
    {"Red  ","Green","Blue ","Color"},
    {"Y-Lumunance","U-Chrome   ","V-Chrome   ","Color     "},
};

#define    XtNdebug "debug"
#define    XtNbatch "batch"
```

```
static  XtResource   resources[] = {
        {XtNdebug, XtCBoolean, XtRBoolean, sizeof(Boolean),
        XtOffset(Global,debug), XtRString, "false"},
        {XtNbatch, XtCFile, XtRString, sizeof(String),
        XtOffset(Global,batch), XtRString, NULL},
};

static  XrmOptionDescRec  options[]={
        {"-debug","*debug",XrmoptionNoArg,"true"},
        {"-batch","*batch",XrmoptionSepArg,NULL},
};

static  Boolean       CvtStringToPixel2();

#if defined(__STDC__)
externalref   XtConvertArgRec    const colorConvertArgs[2];
#else
externalref XtConvertArgRec colorConvertArgs[2];
#endif

static  String fallback_resources[]={
        "*copy_video*Toggle*translations: #override \\n <Btn1Down>,<Btn1Up>:
set() notify()",
        "*copy_video*copy*state: true",
        NULL,
};

XtActionsRec        actionTable[]={
        {"NameButton",NameButton},
};

main(argc,argv,envp)
```

```
int     argc;
char    *argv[], *envp[];

{
        void    InitPixmaps(), InitActions(), InitMain(), InitEnv(), InitDither(), Dispatch();
        GlobalRec       globalrec;

        global=&globalrec;
        global->videos=NULL;
        global->frames=NULL;
        global->points=NULL;
        InitEnv(envp);

global->toplevel=XtAppInitialize(&(global->app_con),"xwave",options,XtNumber(optio
ns),&argc,argv,fallback_resources,NULL,ZERO);

XtGetApplicationResources(global->toplevel,global,resources,XtNumber(resources),NUL
L,ZERO);
        if (global->batch!=NULL) {
                Parse(BATCH_DIR,global->batch,BATCH_EXT);
                if (global->batch_list!=NULL) Dispatch(global->batch_list);
        }
        if (global->batch==NULL) {
                XtAppAddActions(global->app_con,actionTable,XtNumber(actionTable));

XtSetTypeConverter(XtRString,XtRPixel,CvtStringToPixel2,colorConvertArgs,XtNumber
(colorConvertArgs),XtCacheByDisplay,NULL);
                if (global->debug) Dprintf("Xwave Debugging Output\n");
                InitVisual();
                InitDither();
                InitPixmaps(IconPath,IconFile);
                Parse(PalettePath,"xwave",PaletteExt);
```

```
        global->palettes=ReOrderPalettes(global->palettes,global->palettes);
        InitActions(global->app_con);
        InitMain();
        XtRealizeWidget(global->toplevel);
        XtAppMainLoop(global->app_con);
    }
}

void    InitEnv(envp)

char    *envp[];

{
    String  home=NULL, xwave=NULL;

    Dprintf("Initializing enviroment\n");
    while(*envp!=NULL) {
        if(!strncmp(*envp,"HOME=",5)) home=(*envp)+5;
        if(!strncmp(*envp,"XWAVE=",6)) xwave=(*envp)+6;
        envp++;
    }
    if (xwave!=NULL) sprintf(global->home,"%s/",xwave);
    else sprintf(global->home,"%s/xwave/",home);
}

#define     HEIGHT      14

void    InitPixmaps(path,file)

char    *file, *path;

{
```

```
    FILE    *fp, *fopen();
    Icon    icons;
    char    pad[100];
    Display         *dpy=XtDisplay(global->toplevel);
    int     i, j, sink, scrn=XDefaultScreen(dpy), depth=DisplayPlanes(dpy,scrn),
                    bpl=(global->levels*depth+7)/8;
    char    data[HEIGHT*bpl];
    XImage
*image=XCreateImage(dpy,global->visinfo->visual,depth,ZPixmap,0,data,global->leve
ls,HEIGHT,8,bpl);

    sprintf(pad,"%s%s/%s\0",global->home,path,file);
    if (NULL == (fp=fopen(pad,"r"))) {
            Eprintf("Can't open file %s\n",pad);
            exit();
    }
    fscanf(fp,"%d\n",&global->no_icons);
    global->icons=(Icon)MALLOC((1+global->no_icons)*sizeof(IconRec));
    for(i=0;i<global->no_icons;i++) {
            global->icons[i].name=(String)MALLOC(100);
            fscanf(fp,"%s\n",global->icons[i].name);
            sprintf(pad,"%s%s/%s\0",global->home,path,global->icons[i].name);
            XReadBitmapFile(
                    XtDisplay(global->toplevel),
                    XDefaultRootWindow(dpy),
                    pad,
                    &global->icons[i].width,
                    &global->icons[i].height,
                    &global->icons[i].pixmap,
                    &sink,
                    &sink
            );
```

```
        }
        global->icons[global->no_icons].name=(String)MALLOC(100);
        strcpy(global->icons[global->no_icons].name,"colors");
        global->icons[global->no_icons].width=global->levels;
        global->icons[global->no_icons].height=HEIGHT;
        for(i=0;i<global->levels;i++)
                for(j=0;j<HEIGHT;j++) XPutPixel(image,i,j,i);

global->icons[global->no_icons].pixmap=XCreatePixmap(dpy,XDefaultRootWindow(dp
y),global->levels,HEIGHT,depth);

XPutImage(dpy,global->icons[global->no_icons].pixmap,DefaultGC(dpy,scrn),image,0,0
,0,0,global->levels,HEIGHT);
        global->no_icons++;
        XtFree(image);
        fclose(fp);
}

#define done(type, value) \
        {\
                if (toVal->addr != NULL) {              \
                if (toVal->size < sizeof(type)) {       \
                        toVal->size = sizeof(type);     \
                        return False;           \
                }\
                *(type*)(toVal->addr) = (value);        \
                }                       \
                else {                  \
                static type static_val;         \
                static_val = (value);           \
                toVal->addr = (XtPointer)&static_val;   \
                }                       \
```

```
            toVal->size = sizeof(type);          \
            return True;                  \
        }

#define      dist(colora,colorb) \

abs(colora.red-colorb.red)+abs(colora.green-colorb.green)+abs(colora.blue-colorb.blue)

static Boolean CvtStringToPixel2(dpy, args, num_args, fromVal, toVal, closure_ret)
    Display*   dpy;
    XrmValuePtr args;
    Cardinal    *num_args;
    XrmValuePtr       fromVal;
    XrmValuePtr       toVal;
    XtPointer  *closure_ret;
{
    String          str = (String)fromVal->addr;
    XColor          screenColor;
    XColor          exactColor;
    Screen          *screen;
    Colormap        colormap;
    Status          status;
    String          params[1];
    Cardinal        num_params=1;

        Dprintf("Convert string to pixel 2\n");
    if (*num_args != 2)
     XtAppErrorMsg(XtDisplayToApplicationContext(dpy), "wrongParameters",
 "cvtStringToPixel",
                "XtToolkitError",
       "String to pixel conversion needs screen and colormap arguments",
       (String *)NULL, (Cardinal *)NULL);
```

```
screen = *((Screen **) args[0].addr);
colormap = *((Colormap *) args[1].addr);

    if (!strcmp(str,XtDefaultBackground)) {
            *closure_ret = False;
            done(Pixel,WhitePixelOfScreen(screen));
    }
    if (!strcmp(str,XtDefaultForeground)) {
            *closure_ret = False;
            done(Pixel,BlackPixelOfScreen(screen));
    }
    params[0]=str;
    if (0==XParseColor(DisplayOfScreen(screen),colormap,str,&screenColor)) {
            XtAppWarningMsg(XtDisplayToApplicationContext(dpy), "noColormap",
"cvtStringToPixel",
                    "XtToolkitError", "Cannot parse color: \"%s\"",
params,&num_params);
            return False;
    } else {
    if (0==XAllocColor(DisplayOfScreen(screen),colormap,&screenColor)) {
                    int     i, delta, closest=0;
                    XColor      colors[global->levels];

                    for(i=0;i<global->levels;i++) colors[i].pixel=i;

XQueryColors(DisplayOfScreen(screen),colormap,colors,global->levels);
                    delta=dist(screenColor,colors[0]);
                    for(i=1;i<global->levels;i++) {
                            int     delta_new=dist(screenColor,colors[i]);

                            if (delta_new<delta) {
                                    delta=delta_new;
```

```
                                        closest=i;
                                }
                        }
                        Dprintf("Closest color to %s is pixel %d red %d green %d blue
%d\n",str,colors[closest].pixel,colors[closest].red,colors[closest].green,colors[closest].blue
);
                        *closure_ret = (char*)True;
                        done(Pixel, closest);
                } else {
                        *closure_ret = (char*)True;
                        done(Pixel, screenColor.pixel);
                }
        }
}

void    Dispatch(list)

Batch   list;

{
        if (list->next!=NULL) Dispatch(list->next);
        (list->proc)(NULL,list->closure,list->call_data);
        if (list->closure!=NULL) XtFree(list->closure);
        if (list->call_data!=NULL) XtFree(list->call_data);
        XtFree(list);
}

void    BatchCtrl(w,closure,call_data)

Widget          w;
caddr_t         closure, call_data;
```

```
{
	Dprintf("BatchCtrl\n");
	global->batch=(String)closure;
}

void	UnixShell(w,closure,call_data)

Widget		w;
caddr_t		closure, call_data;

{
	if (-1==Fork((char **)closure)) Eprintf("Unable to fork\n");
}

void	InitDither()

{
	int	i, j, k, l,
			dm4[4][4]={
				0,  8,  2, 10,
				12, 4, 14,  6,
				3, 11,  1,  9,
				15, 7, 13,  5
			};

	for(i=0;i<4;i++)
		for(j=0;j<4;j++)
			for(k=0;k<4;k++)
				for(l=0;l<4;l++)

 global->dither[4*k+i][4*l+j]=(dm4[i][j]<<4)+dm4[k][l];
 }
```

source/Copy.h

```
typedef         struct  {
        Video   video;
        char    name[STRLEN], src_name[STRLEN];
        int     UVsample[2];
        int     mode;
        Widget          radioGroup;
} CopyCtrlRec, *CopyCtrl;
```

source/Gram.y

```
%{

/*
 *      Grammar for files: .elo
 */

#include        "../include/xwave.h"
#include        "Klics.h"
#include        "Transform.h"
#include        "Copy.h"
#include        "Video.h"
extern void     VideoLoad();
extern void     VideoSave();
extern void     VideoDrop();
extern void     ImportKlics();
extern void     VideoAbekusSave();
extern void     UnixShell();
extern void     BatchCompCtrl();
extern void     BatchTransCtrl();
extern void     BatchCopyCtrl();
extern void     BatchCompare();
extern void     BatchCtrl();
extern CompCtrl         InitCompCtrl();
extern CopyCtrl         InitCopyCtrl();
extern TransCtrl        InitTransCtrl();

static  char    *ptr;
void    NewBatch();

%}
```

```
%union
{
        double          fnum;
        int     num;
        char    *ptr;
        Boolean         bool;
};

%token      SIZE TRANSFORM TRANSFORM_NONE TRANSFORM_WAVE PATH
%token      FILE_PAL PALETTE RANGE LINE
%token      FILE_VID TYPE FORMAT_MONO FORMAT_RGB FORMAT_YUV
RATE DISK GAMMA PATH FILES START END LEN DIM HEADER OFFSETS
NEGATIVE PRECISION
%token      FILE_BAT LOAD SAVE SAVE_ABEKUS COMPARE DROP
COMPRESS VIDEO_NAME STATS_NAME BIN_NAME
%token      STILL_MODE VIDEO_MODE AUTO_Q QUANT_CONST
THRESH_CONST BASE_FACTOR DIAG_FACTOR CHROME_FACTOR
%token      DECISION DEC_MAX DEC_SIGABS DEC_SIGSQR FEEDBACK
FILTER FLT_NONE FLT_EXP CMP_CONST SPACE LEFT_BRACE RIGHT_BRACE
DIRECTION
%token      FPS BITRATE BUFFER XWAVE SHELL IMPORT_KLICS
%token      COPY DIRECT_COPY DIFF LPF_WIPE LPF_ONLY RGB_YUV
%token      <num>       NUMBER
%token      <ptr>       STRING
%token      <fnum>      FNUMBER
%token      <bool>      BOOLEAN

%type <num>       number video_type decision filter
%type <ptr>       string
%type <fnum>      fnumber
%type <bool>      boolean
```

```
%start wait

%%

wait    :
            | pal_id pal_desc
            | video_id video_desc
            | bat_id bat_desc bat_end;

pal_id  : FILE_PAL {
                    Dprintf("Gram: palette file %s\n",global->parse_file);
            };

video_id        : FILE_VID {
                        Dprintf("Gram: video file %s\n",global->parse_file);
                        global->videos->start=1;
                        global->videos->size[2]=1;
                    };

bat_id          : FILE_BAT {
                        Dprintf("Gram: batch file %s\n",global->parse_file);
                    };

pal_desc        :
                    | pal_desc palette LEFT_BRACE mappings RIGHT_BRACE;

palette             : PALETTE string {
                        Palette         pal=(Palette)MALLOC(sizeof(PaletteRec));

                        Dprintf("Gram: palette %s\n",$2);
                        strcpy(pal->name,$2);
                        pal->mappings=NULL;
```

```
                        pal->next=global->palettes;
                        global->palettes=pal;
                        global->no_pals++;
                };

mappings        :
                | mappings mapping;

mapping         : RANGE number number LINE number number {
                Map     map=(Map)MALLOC(sizeof(MapRec));

                Dprintf("Gram: Range %d to %d m=%d c=%d\n",$2,$3,$5,$6);
                map->start=$2;
                map->finish=$3;
                map->m=$5;
                map->c=$6;
                map->next=global->palettes->mappings;
                global->palettes->mappings=map;
        };

video_desc      : video_defs  {
                        if (global->videos->size[0]==0 &&
global->videos->size[1]==0) {
                                global->videos->size[0]=global->videos->cols;
                                global->videos->size[1]=global->videos->rows;
                        }
                };

video_defs      :
                | video_defs video_def;

video_def       : PATH string {
```

```
        Dprintf("Video path %s\n",$2);
        strcpy(global->videos->path,$2);
}
| FILES string {
        Dprintf("Frames stored in %s\n",$2);
        strcpy(global->videos->files,$2);
}
| TYPE video_type {
        String types[]={"Mono","RGB","YUV"};

        Dprintf("Video type: %s\n",types[$2]);
        global->videos->type=(VideoFormat)$2;
}
| RATE number {
        Dprintf("Video rate %d fps\n",$2);
        global->videos->rate=$2;
}
| DISK {
        Dprintf("Frames on disk\n");
        global->videos->disk=True;
}
| GAMMA {
        Dprintf("Gamma corrected\n");
        global->videos->gamma=True;
}
| NEGATIVE {
        Dprintf("Negative video\n");
        global->videos->negative=True;
}
| TRANSFORM video_transform
| START number {
        Dprintf("Video start %03d\n",$2);
```

```
        global->videos->start=$2;
}
| END number {
        Dprintf("Video end %03d\n",$2);
        global->videos->size[2]=$2-global->videos->start+1;
}
| LEN number {
        Dprintf("Video frames %d\n",$2);
        global->videos->size[2]=$2;
}
| DIM number number {
        Dprintf("Video dimensions %d %d\n",$2,$3);
        global->videos->cols=$2;
        global->videos->rows=$3;
}
| HEADER number {
        Dprintf("Video header size %d\n",$2);
        global->videos->offset=$2;
}
| OFFSETS number number {
        Dprintf("Video offsets %d %d\n",$2,$3);
        global->videos->x_offset=$2;
        global->videos->y_offset=$3;
}
| SIZE number number {
        Dprintf("Video size %d %d\n",$2,$3);
        global->videos->size[0]=$2;
        global->videos->size[1]=$3;
}
| PRECISION number {
        Dprintf("Video precision %d bits\n",8+$2);
        global->videos->precision=$2;
```

```
                };

video_type      : FORMAT_MONO { $$=(int)MONO; }
                | FORMAT_RGB { $$=(int)RGB; }
                | FORMAT_YUV number number { $$=(int)YUV;
global->videos->UVsample[0]=$2; global->videos->UVsample[1]=$3; };

video_transform     : TRANSFORM_NONE {
                            global->videos->trans.type=TRANS_None;
                    }
                    | TRANSFORM_WAVE number number boolean {
                            Dprintf("Video wavelet tranformed %d %d
%s\n",$2,$3,$4?"True":"False");
                            global->videos->trans.type=TRANS_Wave;
                            global->videos->trans.wavelet.space[0]=$2;
                            global->videos->trans.wavelet.space[1]=$3;
                            global->videos->trans.wavelet.dirn=$4;
                    };

bat_end         :
                | XWAVE {
                        Dprintf("Gram: XWAVE\n");
                        NewBatch(BatchCtrl,(caddr_t)NULL,NULL);
                };

bat_desc        : bat_cmds {
                        Dprintf("Gram: End of batch file\n");
                };

bat_cmds        :
                | bat_cmds bat_cmd;
```

```
bat_cmd            : simple_cmd
                   | complex_cmd
                   ;

simple_cmd   : LOAD string {
                        XawListReturnStruct *list_return=(XawListReturnStruct
*)MALLOC(sizeof(XawListReturnStruct));

                        Dprintf("Gram: LOAD %s\n",$2);
                        list_return->string=$2;
                        NewBatch(VideoLoad,NULL,(caddr_t)list_return);
                   }
                   | SAVE string {
                        XawListReturnStruct *list_return=(XawListReturnStruct
*)MALLOC(sizeof(XawListReturnStruct));

                        Dprintf("Gram: SAVE %s\n",$2);
                        list_return->string=$2;
                        NewBatch(VideoSave,NULL,(caddr_t)list_return);
                   }
                   | SAVE_ABEKUS string string string string {
                        AbekusCtrl
ctrl=(AbekusCtrl)MALLOC(sizeof(AbekusCtrlRec));

                        Dprintf("Gram: SAVE_ABEKUS %s %s %s
%s\n",$2,$3,$4,$5);
                        strcpy(ctrl->names[0],$2);
                        strcpy(ctrl->names[1],$3);
                        strcpy(ctrl->names[2],$4);
                        strcpy(ctrl->names[3],$5);
                        NewBatch(VideoAbekusSave,(caddr_t)ctrl,NULL);
                   }
```

```
| COMPARE string string {
        XawListReturnStruct *list_return=(XawListReturnStruct
*)MALLOC(sizeof(XawListReturnStruct));

        Dprintf("Gram: COMPARE %s with %s\n",$2,$3);
        list_return->string=$2;
        NewBatch(BatchCompare,(caddr_t)$3,(caddr_t)list_return);
}
| DROP string {
        XawListReturnStruct *list_return=(XawListReturnStruct
*)MALLOC(sizeof(XawListReturnStruct));

        Dprintf("Gram: DROP %s\n",$2);
        list_return->string=$2;
        NewBatch(VideoDrop,NULL,(caddr_t)list_return);
}
| IMPORT_KLICS string {
        XawListReturnStruct *list_return=(XawListReturnStruct
*)MALLOC(sizeof(XawListReturnStruct));

        Dprintf("Gram: IMPORT_KLICS %s\n",$2);
        list_return->string=$2;
        NewBatch(ImportKlics,NULL,(caddr_t)list_return);
}
| SHELL string {
        char    **argv, *str=$2;
        int     c, argc=1, len=strlen(str);

        Dprintf("Shell %s\n",str);
        for(c=0;c<len;c++) if (str[c]==' ') {
                str[c]='\0';
                argc++;
```

```
                }
                argv=(char **)MALLOC((argc+1)*sizeof(char *));
                argc=0;
                for(c=0;c<len;c+=1+strlen(str+c)) {
                        argv[argc]=(char
*)MALLOC((strlen(str+c)+1)*sizeof(char));
                        strcpy(argv[argc],str+c);
                        argc++;
                }
                argv[argc]=NULL;
                NewBatch(UnixShell,(caddr_t)argv,NULL);
        };

complex_cmd     : compress LEFT_BRACE comp_args RIGHT_BRACE
                | transform LEFT_BRACE trans_args RIGHT_BRACE
                | copy copy_arg;

compress        : COMPRESS string {
                CompCtrl        ctrl=InitCompCtrl($2);

                Dprintf("Gram: COMPRESS\n");
                NewBatch(BatchCompCtrl,(caddr_t)ctrl,NULL);
        };

transform       : TRANSFORM string {
                TransCtrl       ctrl=InitTransCtrl($2);

                Dprintf("Gram: TRANSFORM\n");
                NewBatch(BatchTransCtrl,(caddr_t)ctrl,NULL);
        };

copy            : COPY string string {
```

```
                CopyCtrl      ctrl=InitCopyCtrl($2);
                Dprintf("Gram: Copy\n");
                strcpy(ctrl->name,$3);
                NewBatch(BatchCopyCtrl,(caddr_t)ctrl,NULL);
            };

comp_args   :
            | comp_args comp_arg;

trans_args  :
            | trans_args trans_arg;

copy_arg    : DIRECT_COPY number number {
                Dprintf("Gram: Direct Copy (sample %d %d)\n",$2,$3);
                ((CopyCtrl)global->batch_list->closure)->mode=1;

((CopyCtrl)global->batch_list->closure)->UVsample[0]=$2;

((CopyCtrl)global->batch_list->closure)->UVsample[1]=$3;
            }
            | DIFF {
                Dprintf("Gram: Differance Copy\n");
                ((CopyCtrl)global->batch_list->closure)->mode=2;
            }
            | LPF_WIPE {
                Dprintf("Gram: LPF zero\n");
                ((CopyCtrl)global->batch_list->closure)->mode=3;
            }
            | LPF_ONLY {
                Dprintf("Gram: LPF only\n");
                ((CopyCtrl)global->batch_list->closure)->mode=4;
            }
```

```
                | RGB_YUV {
                        Dprintf("Gram: RGB/YUV\n");
                        ((CopyCtrl)global->batch_list->closure)->mode=5;
                }
                | GAMMA {
                        Dprintf("Gram: Gamma convert\n");
                        ((CopyCtrl)global->batch_list->closure)->mode=6;
                };

comp_arg        : VIDEO_NAME string {
                        Dprintf("Gram: Compress name %s\n",$2);

strcpy(((CompCtrl)global->batch_list->closure)->name,$2);
                }
                | STATS_NAME string {
                        Dprintf("Gram: Stats name %s\n",$2);

strcpy(((CompCtrl)global->batch_list->closure)->stats_name,$2);

((CompCtrl)global->batch_list->closure)->stats_switch=True;
                }
                | BIN_NAME string {
                        Dprintf("Gram: Bin name %s\n",$2);

strcpy(((CompCtrl)global->batch_list->closure)->bin_name,$2);

((CompCtrl)global->batch_list->closure)->bin_switch=True;
                }
                | STILL_MODE {
                        Dprintf("Gram: Still\n");
                        ((CompCtrl)global->batch_list->closure)->stillvid=True;
                }
```

```
| VIDEO_MODE {
        Dprintf("Gram: Video\n");
        ((CompCtrl)global->batch_list->closure)->stillvid=False;
}
| AUTO_Q boolean {
        Dprintf("Gram: Auto_q %s\n",$2?"True":"False");
        ((CompCtrl)global->batch_list->closure)->auto_q=$2;
}
| QUANT_CONST fnumber {
        Dprintf("Gram: Quant const %f\n",$2);

((CompCtrl)global->batch_list->closure)->quant_const=$2;
}
| THRESH_CONST fnumber {
        Dprintf("Gram: Thresh const %f\n",$2);

((CompCtrl)global->batch_list->closure)->thresh_const=$2;
}
| BASE_FACTOR number fnumber {
        Dprintf("Gram: Base factor oct %d=%f\n",$2,$3);

((CompCtrl)global->batch_list->closure)->base_factors[$2]=$3;
}
| DIAG_FACTOR fnumber {
        Dprintf("Gram: Diag factor %f\n",$2);
        ((CompCtrl)global->batch_list->closure)->diag_factor=$2;
}
| CHROME_FACTOR fnumber {
        Dprintf("Gram: Chrome factor %f\n",$2);

((CompCtrl)global->batch_list->closure)->chrome_factor=$2;
}
```

```
| DECISION decision {
        Dprintf("Gram: Decision changed\n");
        ((CompCtrl)global->batch_list->closure)->decide=$2;
}
| FEEDBACK number {
        ((CompCtrl)global->batch_list->closure)->feedback=$2;
        ((CompCtrl)global->batch_list->closure)->auto_q=True;
}
| FILTER filter {
        String  filters[2]={"None","Exp"};
        Dprintf("Gram: Filter %s\n",filters[$2]);
        ((CompCtrl)global->batch_list->closure)->filter=$2;
}
| CMP_CONST fnumber {
        Dprintf("Gram: Comparison %f\n",$2);
        ((CompCtrl)global->batch_list->closure)->cmp_const=$2;
}
| FPS fnumber {
        Dprintf("Gram: Frame Rate %f\n",$2);
        ((CompCtrl)global->batch_list->closure)->fps=$2;
}
| BITRATE number {
        Dprintf("Gram: %dx64k/s\n",$2);
        ((CompCtrl)global->batch_list->closure)->bitrate=$2;
}
| BUFFER {
        Dprintf("Gram: Buffer on\n");

((CompCtrl)global->batch_list->closure)->buf_switch=True;
};

decision        : DEC_MAX{ $$ = 0; }
```

```
                | DEC_SIGABS { $$ = 1; }
                | DEC_SIGSQR { $$ = 2; };

filter      : FLT_NONE { $$ = 0; }
                | FLT_EXP { $$ = 1; };

trans_arg   : VIDEO_NAME string {
                        Dprintf("Gram: Transform name %s\n",$2);

strcpy(((TransCtrl)global->batch_list->closure)->name,$2);
                }
                | DIRECTION boolean {
                        Dprintf("Gram: Direction %s\n",$2?"True":"False");
                        ((TransCtrl)global->batch_list->closure)->dirn=$2;
                }
                | SPACE number number {
                        Dprintf("Gram: Space %d %d\n",$2,$3);
                        ((TransCtrl)global->batch_list->closure)->space[0]=$2;
                        ((TransCtrl)global->batch_list->closure)->space[1]=$3;
                }
                | PRECISION number {
                        Dprintf("Gram: Precision %d bits\n",8+$2);
                        ((TransCtrl)global->batch_list->closure)->precision=$2;
                };

boolean     : BOOLEAN { $$ = $1; };

string  : STRING    {
                ptr = (char *)malloc(strlen($1)+1);
                strcpy(ptr,1+$1);
                ptr[strlen(ptr)-1]='\0';
                $$ = ptr;
```

```
        };

fnumber     : FNUMBER { $$ = $1; };

number      : NUMBER   { $$ = $1; };

%%
yyerror(s) char *s; {
        Eprintf("Gram: error %s\n",s);
        exit(3);
}

void    NewBatch(proc,closure,call_data)

Proc    proc;
caddr_t         closure, call_data;

{
                        Batch   bat=(Batch)MALLOC(sizeof(BatchRec));

                        bat->proc=proc;
                        bat->closure=closure;
                        bat->call_data=call_data;
                        bat->next=global->batch_list;
                        global->batch_list=bat;
}
```

source/Klics.h

```
/* Block size - no not change */
#define     BLOCK     2

typedef int Block[BLOCK][BLOCK]; /* small block */

/* tokens */
#define     TOKENS    15

#define ZERO_STILL          0
#define NON_ZERO_STILL      1
#define BLOCK_SAME          2
#define ZERO_VID            3
#define BLOCK_CHANGE        4
#define LOCAL_ZERO          5
#define LOCAL_NON_ZERO      6
#define CHANNEL_ZERO        7
#define CHANNEL_NON_ZERO    8
#define OCT_ZERO            9
#define OCT_NON_ZERO        10
#define LPF_ZERO            11
#define LPF_NON_ZERO        12
#define LPF_LOC_ZERO        13
#define LPF_LOC_NON_ZERO    14

static int                          token_bits[TOKENS]
={1,1,1,2,2,1,1,1,1,1,1,1,1,1,1};
static unsigned char   token_codes[TOKENS]={0,1,0,1,3,0,1,0,1,0,1,0,1,0,1};
```

```
/* decision algorithms */
#define MAXIMUM 0
#define SIGABS  1
#define SIGSQR  2

/* compression modes */
#define STILL   0
#define SEND    1
#define VOID    2
#define STOP    3

/* LookAhead histogram */
#define     HISTO       400
#define     HISTO_DELTA     20.0
#define     HISTO_BITS 9

#include    "../include/Bits.h"

typedef     struct  {
        Video src, dst;
        Boolean     stillvid, stats_switch, bin_switch, auto_q, buf_switch;
        double      quant_const, thresh_const, cmp_const, fps,
                    base_factors[5], diag_factor, chrome_factor;
        int     bitrate, feedback, decide, filter;
        char    name[STRLEN], stats_name[STRLEN], bin_name[STRLEN],
src_name[STRLEN];
        Bits    bfp;
} CompCtrlRec, *CompCtrl;

typedef     struct  {
        Boolean     stillvid, auto_q, buf_switch;
        double      quant_const, thresh_const, cmp_const, fps,
```

```
                base_factors[5], diag_factor, chrome_factor;
    int     decide;
    VideoFormat  type;
    Boolean     disk, gamma;
    int     rate, start, size[3], UVsample[2];
    VideoTrans   trans;
    int     precision;
} KlicsHeaderRec, *KlicsHeader;
```

source/KlicsSA.h

```
#include <stdio.h>
#include	"Bits.h"

#define	negif(bool,value)	((bool)?-(value):(value))

extern Bits	bopen();
extern void	bclose(), bread(), bwrite(), bflush();

/* Stand Alone definitions to replace VideoRec & CompCtrl assumes:
 *	video->type == YUV;
 *	video->UVsample[]={1,1};
 * video->trans.wavelet.space[]={3,2};
 *	ctrl->bin_switch == True;
 */

#define SA_WIDTH	352
#define SA_HEIGHT		288
#define	SA_PRECISION	2
static	double	base_factors[5]={1.0,0.32,0.16,0.16,0.16};
#define	diag_factor	1.4142136
#define chrome_factor	2.0
#define	thresh_const	0.6
#define	cmp_const	0.9

/* Block size - no not change */
#define	BLOCK	2

typedef int Block[BLOCK][BLOCK]; /* small block */
```

```
/* tokens */
#define         TOKENS      15

#define ZERO_STILL          0
#define NON_ZERO_STILL      1
#define BLOCK_SAME          2
#define ZERO_VID            3
#define BLOCK_CHANGE        4
#define LOCAL_ZERO          5
#define LOCAL_NON_ZERO      6
#define CHANNEL_ZERO        7
#define CHANNEL_NON_ZERO    8
#define OCT_ZERO            9
#define OCT_NON_ZERO        10
#define LPF_ZERO            11
#define LPF_NON_ZERO        12
#define LPF_LOC_ZERO        13
#define LPF_LOC_NON_ZERO    14

static int                        token_bits[TOKENS]
={1,1,1,2,2,1,1,1,1,1,1,1,1,1,1};
static unsigned char  token_codes[TOKENS]={0,1,0,1,3,0,1,0,1,0,1,0,1,0,1};

/* decision algorithms */
#define MAXIMUM 0
#define SIGABS  1
#define SIGSQR  2

/* compression modes */
#define STILL   0
#define SEND    1
#define VOID    2
```

```
#define STOP    3

/* LookAhead histogram */
#define     HISTO       400
#define     HISTO_DELTA     20.0
#define     HISTO_BITS 9
```

source/Lex.l

```
%{

/*
 *      Lex driver for input files: .pal .vid .bat
 */

#include        "../include/xwave.h"
#include        "../include/Gram.h"
extern int      ParseInput();

#undef          unput
#undef          input
#undef          output
#undef          feof
#define         unput(c)        ungetc(c,global->parse_fp)
#define         input()                 ParseInput(global->parse_fp)
#define         output(c)       putchar(c)
#define         feof()          (1)

%}

number          -?[0-9]+
fnumber         -?[0-9]+"."[0-9]+
string  \"([^"]|\\.)*\"
%start WAIT MAP VIDEO BATCH BATCH_TRANS BATCH_COMP
%n 2000
%p 4000
%e 2000
```

```
%%

"/*"  {       char   c='\0';

                     while(c!='/') {
                             while (c!='*') c=input();
                             while (c=='*') c=input();
                     }
              }

\.pal  { BEGIN MAP; Dprintf("Lex: Reading palette file\n"); return(FILE_PAL); }
\.vid  { BEGIN VIDEO; Dprintf("Lex: Reading video file\n"); return(FILE_VID); }
\.bat  { BEGIN BATCH; Dprintf("Lex: Reading batch file\n"); return(FILE_BAT); }

{number}          { (void)sscanf(yytext, "%d", &yylval.num); return(NUMBER); }
{string}          { yylval.ptr = (char *)yytext; return(STRING); }
{fnumber}         { (void)sscanf(yytext, "%lf", &yylval.fnum); return(FNUMBER); }

<MAP>Palette      { return(PALETTE); }
<MAP>\{                  { return(LEFT_BRACE); }
<MAP>\}                  { return(RIGHT_BRACE); }
<MAP>Range               { return(RANGE); }
<MAP>Line                { return(LINE); }

<VIDEO>Type              { return(TYPE); }
<VIDEO>MONO              { return(FORMAT_MONO); }
<VIDEO>RGB               { return(FORMAT_RGB); }
<VIDEO>YUV               { return(FORMAT_YUV); }
<VIDEO>Rate              { return(RATE); }
<VIDEO>Disk              { return(DISK); }
<VIDEO>Gamma  { return(GAMMA); }
<VIDEO>Negative          { return(NEGATIVE); }
```

```
<VIDEO>Path          { return(PATH); }
<VIDEO>Files         { return(FILES); }
<VIDEO>Transform     { return(TRANSFORM); }
<VIDEO>None          { return(TRANSFORM_NONE); }
<VIDEO>Wavelet       { return(TRANSFORM_WAVE); }
<VIDEO>Start         { return(START); }
<VIDEO>End           { return(END); }
<VIDEO>Length        { return(LEN); }
<VIDEO>Dimensions    { return(DIM); }
<VIDEO>Header        { return(HEADER); }
<VIDEO>Offsets       { return(OFFSETS); }
<VIDEO>Size          { return(SIZE); }
<VIDEO>Precision     { return(PRECISION); }
<VIDEO>Yes           { yylval.bool=True; return(BOOLEAN); }
<VIDEO>No            { yylval.bool=False; return(BOOLEAN); }

<BATCH>Load          { return(LOAD); }
<BATCH>Save          { return(SAVE); }
<BATCH>SaveAbekus    { return(SAVE_ABEKUS); }
<BATCH>Compare       { return(COMPARE); }
<BATCH>Drop          { return(DROP); }
<BATCH>ImportKLICS   { return(IMPORT_KLICS); }
<BATCH>Transform     { BEGIN BATCH_TRANS; return(TRANSFORM); }
<BATCH>Compress      { BEGIN BATCH_COMP; return(COMPRESS); }
<BATCH>Xwave         { return(XWAVE); }
<BATCH>Shell         { return(SHELL); }
<BATCH>Copy          { return(COPY); }
<BATCH>Direct        { return(DIRECT_COPY); }
<BATCH>Diff          { return(DIFF); }
<BATCH>LPFzero       { return(LPF_WIPE); }
<BATCH>LPFonly       { return(LPF_ONLY); }
<BATCH>RGB-YUV       { return(RGB_YUV); }
```

```
<BATCH>Gamma             { return(GAMMA); }

<BATCH_COMP>VideoName    { return(VIDEO_NAME); }
<BATCH_COMP>Stats        { return(STATS_NAME); }
<BATCH_COMP>Binary       { return(BIN_NAME); }
<BATCH_COMP>Yes                  { yylval.bool=True; return(BOOLEAN); }
<BATCH_COMP>No                   { yylval.bool=False; return(BOOLEAN); }
<BATCH_COMP>Still        { return(STILL_MODE); }
<BATCH_COMP>Video        { return(VIDEO_MODE); }
<BATCH_COMP>AutoQuant    { return(AUTO_Q); }
<BATCH_COMP>QuantConst   { return(QUANT_CONST); }
<BATCH_COMP>ThreshConst  { return(THRESH_CONST); }
<BATCH_COMP>BaseFactor   { return(BASE_FACTOR); }
<BATCH_COMP>DiagFactor   { return(DIAG_FACTOR); }
<BATCH_COMP>ChromeFactor { return(CHROME_FACTOR); }
<BATCH_COMP>Decision     { return(DECISION); }
<BATCH_COMP>Feedback     { return(FEEDBACK); }
<BATCH_COMP>Maximum              { return(DEC_MAX); }
<BATCH_COMP>SigmaAbs     { return(DEC_SIGABS); }
<BATCH_COMP>SigmaSqr     { return(DEC_SIGSQR); }
<BATCH_COMP>Filter       { return(FILTER); }
<BATCH_COMP>None         { return(FLT_NONE); }
<BATCH_COMP>Exp                  { return(FLT_EXP); }
<BATCH_COMP>CmpConst     { return(CMP_CONST); }
<BATCH_COMP>FrameRate    { return(FPS); }
<BATCH_COMP>Bitrate      { return(BITRATE); }
<BATCH_COMP>Buffer       { return(BUFFER); }
<BATCH_COMP>\{                   { return(LEFT_BRACE); }
<BATCH_COMP>\}                   { END; BEGIN BATCH;
return(RIGHT_BRACE); }

<BATCH_TRANS>VideoName   { return(VIDEO_NAME); }
```

```
<BATCH_TRANS>Direction      { return(DIRECTION); }
<BATCH_TRANS>Space { return(SPACE); }
<BATCH_TRANS>Precision      { return(PRECISION); }
<BATCH_TRANS>Yes            { yylval.bool=True; return(BOOLEAN); }
<BATCH_TRANS>No                     { yylval.bool=False; return(BOOLEAN); }
<BATCH_TRANS>\{                     { return(LEFT_BRACE); }
<BATCH_TRANS>\}             { END; BEGIN BATCH; return(RIGHT_BRACE); }

[. \t\n]             { ; }

%%
yywrap() { return(1); }
```

source/Transform.h

```
typedef         struct  {
        Video src;
        char    name[STRLEN], src_name[STRLEN];
        int     space[2], precision;
        Boolean dirn;
} TransCtrlRec, *TransCtrl;
```

source/Video.h

```
typedef struct {
	char	names[4][STRLEN];
} AbekusCtrlRec, *AbekusCtrl;
```

source/makefile

```
# Xwave Makefile
#
CFLAGS = -O -I../include
LIBS   = -lXaw -lXmu -lXt -lXext -lX11 -lm -ll -L/usr/openwin/lib

.KEEP_STATE:
.SUFFIXES: .c .o

xwaveSRC = Select.c Convert.c xwave.c InitMain.c Pop2.c Video2.c Malloc.c
InitFrame.c \
		Frame.c Transform.c Convolve3.c Update.c Image.c Menu.c
PullRightMenu.c \
		NameButton.c SmeBSBpr.c Process.c Lex.c Gram.c Parse.c Color.c \
		Bits.c Storage.c Copy.c Message.c Palette.c ImportKlics.c Icon3.c Klics5.c
\
		KlicsSA.c KlicsTestSA.c ImportKlicsSA.c ImpKlicsTestSA.c

objDIR = ../$(ARCH)

xwaveOBJ = $(xwaveSRC:%.c=$(objDIR)/%.o)

$(objDIR)/xwave: $(xwaveOBJ)
	gcc -o $@ $(xwaveOBJ) $(LIBS) $(CFLAGS)
	echo ●●●●●●●●●●●●●●●●●●●●●●

$(xwaveOBJ): $$(@F:.o=.c) ../include/xwave.h
	gcc -c $(@F:.o=.c) $(CFLAGS) -o $@

Lex.c: Gram.c Lex.l
```

```
        lex Lex.l
        mv lex.yy.c Lex.c

Gram.c: Gram.y
        bison -dlt Gram.y
        mv $(@F:.c=.tab.h) ../include/Gram.h
        mv $(@F:.c=.tab.c) Gram.c
```

include/Bits.h

```
#ifndef _Bits_h
#define _Bits_h

typedef     struct  {
        unsigned      char    buf;
        int     bufsize;
        FILE  *fp;
} BitsRec, *Bits;

#endif
```

include/DTheader.h

```
typedef struct DTheader {
    char file_id[8];            /* "DT-IMAGE" */
    char struct_id;             /* 1 */
        char prod_id;               /* 4 */
        char util_id;               /* 1 */
        char board_id;                  /* 2 */
        char create_time[9];  /* [0-1]year, [2]month, [3]dayofmonth, [4]dayofweek,
[5]hour, [6]min, [7]sec, [8]sec/100 */
        char mod_time[9];           /* as create_time */
        char datum;                     /* 1 */
        char datasize[4];           /* 1024?? */
        char file_struct;           /* 1 */
        char datatype;                  /* 1 */
        char compress;                  /* 0 */
        char store;                     /* 1 */
        char aspect[2];                 /* 4, 3 */
        char bpp;                       /* 8 */
        char spatial;               /* 1 */
        char width[2];                  /* 512 */
        char height[2];                 /* 512 */
        char full_width[2];         /* 512 */
        char full_height[2];  /* 512 */
        char unused1[45];
        char comment[160];
        char unused2[256];
} DTheader;
```

include/Icon.h

```
typedef     enum {
        FW_label, FW_icon, FW_command, FW_text, FW_button, FW_icon_button,
FW_view, FW_toggle,
        FW_yn,
        FW_up, FW_down, FW_integer,
        FW_scroll, FW_float,
        FW_form,
} FormWidgetType;

typedef     enum {
        SW_below, SW_over, SW_top, SW_menu,
} ShellWidgetType;

typedef     struct {
        String  name;
        String  contents;
        int             fromHoriz, fromVert;
        FormWidgetType      type;
        String  hook;
} FormItem;
```

include/Image.h

```
/*
 * $XConsortium: Image.h,v 1.24 89/07/21 01:48:51 kit Exp $
 */

/***********************************************************
```

```
ARISING OUT OF OR IN CONNECTION WITH THE USE OR PERFORMANCE OF
THIS
SOFTWARE.

******************************************************************/

#ifndef _XawImage_h
#define _XawImage_h

/*********************************************************************
 *
 * Image Widget
 *
 *********************************************************************/

#include <X11/Xaw/Simple.h>
#include <X11/Xmu/Converters.h>

/* Resources:

 Name                  Class              RepType          Default Value
 ----                  -----              -------          -------------
 border                BorderColor        Pixel            XtDefaultForeground
 borderWidth           BorderWidth        Dimension        1
 cursor                Cursor             Cursor           None
 destroyCallback       Callback           XtCallbackList   NULL
 insensitiveBorder     Insensitive        Pixmap           Gray
 mappedWhenManaged     MappedWhenManaged  Boolean          True
 sensitive             Sensitive          Boolean          True
 bitmap                Bitmap             Pixmap           NULL
 callback              Callback           XtCallbackList   NULL
 x                     Position           Position         0
```

```
y                 Position          Position        0

*/

#define XtNbitmap   "bitmap"

#define XtCBitmap   "Bitmap"

/* Class record constants */

extern WidgetClass imageWidgetClass;

typedef struct _ImageClassRec *ImageWidgetClass;
typedef struct _ImageRec      *ImageWidget;

#endif /* _XawImage_h */
/* DON'T ADD STUFF AFTER THIS #endif */
```

include/ImageHeader.h

```
/* Author: Philip R. Thompson
 * Address: phils@athena.mit.edu, 9-526
 * Note: size of header should be 1024 (1K) bytes.
 * $Header: ImageHeader.h,v 1.2 89/02/13 09:01:36 phils Locked $
 * $Date: 89/02/13 09:01:36 $
 * $Source: /mit/phils/utils/RCS/ImageHeader.h,v $
 */

#define IMAGE_VERSION    3

typedef struct ImageHeader {
    char file_version[8];   /* header version */
    char header_size[8];    /* Size of file header in bytes  */
    char image_width[8];    /* Width of the raster image */
    char image_height[8];   /* Height of the raster imgage */
    char num_colors[8];     /* Actual number of entries in c_map */
    char num_channels[8];   /* 0 or 1 = pixmap, 3 = RG&B buffers */
    char num_pictures[8];   /* Number of pictures in file */
    char alpha_channel[4];  /* Alpha channel flag */
    char runlength[4];      /* Runlength encoded flag */
    char author[48];        /* Name of who made it */
    char date[32];          /* Date and time image was made */
    char program[16];       /* Program that created this file */
    char comment[96];       /* other viewing info. for this image */
    unsigned char c_map[256][3]; /* RGB values of the pixmap indices */
} ImageHeader;


/* Note:
 * - All data is in char's in order to maintain easily portability
```

```
*  across machines and some human readibility.
* - Images may be stored as pixmaps or in seperate channels, such as
*  red, green, blue data.
* - An optional alpha channel is seperate and is found after every
*  num_channels of data.
* - Pixmaps, red, green, blue, alpha and other channel data are stored
*  sequentially after the header.
* - If num_channels = 1 or 0, a pixmap is assumed and up to num_colors
*  of colormap in the header are used.
*/

/*** end ImageHeader.h ***/
```

include/ImageP.h

```
/*
* $XConsortium: ImageP.h,v 1.24 89/06/08 18:05:01 swick Exp $
*/
```

```
TORTIOUS ACTION,
ARISING OUT OF OR IN CONNECTION WITH THE USE OR PERFORMANCE OF
THIS
SOFTWARE.

***********************************************************************/

/*
 * ImageP.h - Private definitions for Image widget
 *
 */

#ifndef _XawImageP_h
#define _XawImageP_h

/***********************************************************************
 *
 * Image Widget Private Data
 *
 ***********************************************************************/

#include "../include/Image.h"
#include <X11/Xaw/SimpleP.h>

/* New fields for the Image widget class record */

typedef struct {int foo;} ImageClassPart;

/* Full class record declaration */
typedef struct _ImageClassRec {
   CoreClassPart      core_class;
   SimpleClassPart    simple_class;
```

```
    ImageClassPart    image_class;
} ImageClassRec;

extern ImageClassRec imageClassRec;

/* New fields for the Image widget record */
typedef struct {
    /* resources */
        Pixmap        pixmap;
        XtCallbackList        callbacks;

    /* private state */
        Dimension    map_width, map_height;
} ImagePart;


/*******************************************************************
 *
 * Full instance record declaration
 *
 *******************************************************************/

typedef struct _ImageRec {
    CorePart    core;
    SimplePart        simple;
    ImagePart  image;
} ImageRec;

#endif /* _XawImageP_h */
```

include/Message.h

```
typedef         struct {
        Widget          shell, widget; /* shell and text widgets (NULL if not created */
        XawTextBlock            info;  /* Display text */
        int     size, rows, cols;      /* Size of buffer (info.ptr) & dimensions of display */
        XawTextEditType    edit;       /* edit type */
        Boolean         own_text;               /* text is owned by message? */
} MessageRec, *Message;
```

include/Palette.h

```
#define PalettePath "."
#define      PaletteExt    ".pal"

typedef      struct  _MapRec {
        int     start, finish, m, c;
        struct  _MapRec      *next;
} MapRec, *Map;

typedef      struct  _PaletteRec {
        char    name[STRLEN];
        Map     mappings;
        struct  _PaletteRec    *next;
} PaletteRec, *Palette;
```

include/PullRightMenu.h

```
/*
 * $XConsortium: PullRightMenu.h,v 1.17 89/12/11 15:01:55 kit Exp $
 *
 * Copyright 1989 Massachusetts Institute of Technology
 *
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 * documentation for any purpose is hereby granted without fee, provided that
 * the above copyright notice appear in all copies and that both that
 * copyright notice and this permission notice appear in supporting
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WHETHER IN AN ACTION
 * OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS ACTION, ARISING OUT
OF OR IN
 * CONNECTION WITH THE USE OR PERFORMANCE OF THIS SOFTWARE.
 *
 */
```

```
/*
 * PullRightMenu.h - Public Header file for PullRightMenu widget.
 *
 * This is the public header file for the Athena PullRightMenu widget.
 * It is intended to provide one pane pulldown and popup menus within
 * the framework of the X Toolkit.  As the name implies it is a first and
 * by no means complete implementation of menu code. It does not attempt to
 * fill the needs of all applications, but does allow a resource oriented
 * interface to menus.
 *
 */

#ifndef _PullRightMenu_h
#define _PullRightMenu_h

#include <X11/Shell.h>
#include <X11/Xmu/Converters.h>

/*******************************************************************
 *
 * PullRightMenu widget
 *
 *******************************************************************/

/* PullRightMenu Resources:

 Name               Class              RepType      Default Value
 ----               -----              -------      -------------
 background         Background         Pixel        XtDefaultBackground
 backgroundPixmap   BackgroundPixmap   Pixmap       None
 borderColor        BorderColor        Pixel        XtDefaultForeground
 borderPixmap       BorderPixmap       Pixmap       None
```

borderWidth	BorderWidth	Dimension	1
bottomMargin	VerticalMargins	Dimension	VerticalSpace
columnWidth	ColumnWidth	Dimension	Width of widest text
cursor	Cursor	Cursor	None
destroyCallback	Callback	Pointer	NULL
height	Height	Dimension	0
label	Label	String	NULL (No label)
labelClass	LabelClass	Pointer	smeBSBObjectClass
mappedWhenManaged	MappedWhenManaged	Boolean	True
rowHeight	RowHeight	Dimension	Height of Font
sensitive	Sensitive	Boolean	True
topMargin	VerticalMargins	Dimension	VerticalSpace
width	Width	Dimension	0
button	Widget	Widget	NULL
x	Position	Position	0
y	Position	Position	0

```
*/

typedef struct _PullRightMenuClassRec*    PullRightMenuWidgetClass;
typedef struct _PullRightMenuRec*         PullRightMenuWidget;

extern WidgetClass pullRightMenuWidgetClass;

#define XtNcursor "cursor"
#define XtNbottomMargin "bottomMargin"
#define XtNcolumnWidth "columnWidth"
#define XtNlabelClass "labelClass"
#define XtNmenuOnScreen "menuOnScreen"
#define XtNpopupOnEntry "popupOnEntry"
#define XtNrowHeight "rowHeight"
#define XtNtopMargin "topMargin"
```

```
#define XtNbutton    "button"

#define XtCColumnWidth "ColumnWidth"
#define XtCLabelClass "LabelClass"
#define XtCMenuOnScreen "MenuOnScreen"
#define XtCPopupOnEntry "PopupOnEntry"
#define XtCRowHeight "RowHeight"
#define XtCVerticalMargins "VerticalMargins"
#define        XtCWidget    "Widget"

/***************************************************************
 *
 * Public Functions.
 *
 ***************************************************************/

/*      Function Name: XawPullRightMenuAddGlobalActions
 *      Description: adds the global actions to the simple menu widget.
 *      Arguments: app_con - the appcontext.
 *      Returns: none.
 */

void
XawpullRightMenuAddGlobalActions(/* app_con */);
/*
XtAppContext app_con;
*/

#endif /* _PullRightMenu_h */
```

include/SmeBSBpr.h

```
/*
 * $XConsortium: SmeBSB.h,v 1.5 89/12/11 15:20:14 kit Exp $
 *
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 *
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 * documentation for any purpose is hereby granted without fee, provided that
 * the above copyright notice appear in all copies and that both that
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 * BE LIABLE FOR ANY SPECIAL, INDIRECT OR CONSEQUENTIAL DAMAGES
OR ANY DAMAGES
 * WHATSOEVER RESULTING FROM LOSS OF USE, DATA OR PROFITS,
WHETHER IN AN ACTION
 * OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS ACTION, ARISING OUT
OF OR IN
 * CONNECTION WITH THE USE OR PERFORMANCE OF THIS SOFTWARE.
 */
```

```
/*
 * SmeBSBpr.h - Public Header file for SmeBSB object.
 *
 * This is the public header file for the Athena BSB Sme object.
 * It is intended to be used with the simple menu widget.  This object
 * provides bitmap - string - bitmap style entries.
 *
 */

#ifndef _SmeBSBpr_h
#define _SmeBSBpr_h

#include <X11/Xmu/Converters.h>

#include <X11/Xaw/Sme.h>

/****************************************************************
 *
 * SmeBSBpr object
 *
 ****************************************************************/

/* BSB pull-right Menu Entry Resources:

Name            Class       RepType         Default Value
----            -----       -------         -------------
callback        Callback    Callback        NULL
destroyCallback Callback    Pointer         NULL
font            Font        XFontStruct *   XtDefaultFont
foreground      Foreground  Pixel           XtDefaultForeground
height          Height      Dimension       0
label           Label       String          Name of entry
```

```
leftBitmap       LeftBitmap          Pixmap       None
leftMargin       HorizontalMargins   Dimension    4
rightBitmap      RightBitmap         Pixmap       None
rightMargin      HorizontalMargins   Dimension    4
sensitive        Sensitive           Boolean      True
vertSpace        VertSpace           int          25
width            Width               Dimension    0
x                Position            Position     0n
y                Position            Position     0
menuName  MenuName  String "menu"

*/

typedef struct _SmeBSBprClassRec    *SmeBSBprObjectClass;
typedef struct _SmeBSBprRec         *SmeBSBprObject;

extern WidgetClass smeBSBprObjectClass;

#define XtNleftBitmap "leftBitmap"
#define XtNleftMargin "leftMargin"
#define XtNrightBitmap "rightBitmap"
#define XtNrightMargin "rightMargin"
#define XtNvertSpace   "vertSpace"
#define        XtNmenuName        "menuName"

#define XtCLeftBitmap "LeftBitmap"
#define XtCHorizontalMargins "HorizontalMargins"
#define XtCRightBitmap "RightBitmap"
#define XtCVertSpace   "VertSpace"
#define        XtCMenuName        "MenuName"

#endif /* _SmeBSBpr_h */
```

include/SmeBSBprP.h

```
/*
 * $XConsortium: SmeBSBP.h,v 1.6 89/12/11 15:20:15 kit Exp $
 *
 * Copyright 1989 Massachusetts Institute of Technology
 *
 * Permission to use, copy, modify, distribute, and sell this software and its
 * documentation for any purpose is hereby granted without fee, provided that
 * the above copyright notice appear in all copies and that both that
 * copyright notice and this permission notice appear in supporting
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OR ANY DAMAGES
 * WHATSOEVER RESULTING FROM LOSS OF USE, DATA OR PROFITS,
WHETHER IN AN ACTION
 * OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS ACTION, ARISING OUT
OF OR IN
 * CONNECTION WITH THE USE OR PERFORMANCE OF THIS SOFTWARE.
 *
 * Author:  Chris D. Peterson, MIT X Consortium
```

```
*/

/*
 * SmeP.h - Private definitions for Sme object
 *
 */

#ifndef _XawSmeBSBP_h
#define _XawSmeBSBP_h

/***********************************************************************
 *
 * Sme Object Private Data
 *
 ***********************************************************************/

#include <X11/Xaw/SmeP.h>
#include "../include/SmeBSBpr.h"

/************************************************************
 *
 * New fields for the Sme Object class record.
 *
 ************************************************************/

typedef struct _SmeBSBprClassPart {
  XtPointer extension;
} SmeBSBprClassPart;

/* Full class record declaration */
typedef struct _SmeBSBprClassRec {
    RectObjClassPart        rect_class;
```

```
    SmeClassPart     sme_class;
    SmeBSBprClassPart  sme_bsb_class;
} SmeBSBprClassRec;

extern SmeBSBprClassRec smeBSBprClassRec;

/* New fields for the Sme Object record */
typedef struct {
    /* resources */
    String label;              /* The entry label. */
    int vert_space;            /* extra vert space to leave, as a percentage
                                  of the font height of the label. */
    Pixmap left_bitmap, right_bitmap; /* bitmaps to show. */
    Dimension left_margin, right_margin; /* left and right margins. */
    Pixel foreground;          /* foreground color. */
    XFontStruct * font;              /* The font to show label in. */
    XtJustify justify;         /* Justification for the label. */
        String  menu_name;  /* Popup menu name */

/* private resources. */

    Boolean set_values_area_cleared; /* Remember if we need to unhighlight. */
    GC norm_gc;                      /* noral color gc. */
    GC rev_gc;                       /* reverse color gc. */
    GC norm_gray_gc;                 /* Normal color (grayed out) gc. */
    GC invert_gc;              /* gc for flipping colors. */

    Dimension left_bitmap_width; /* size of each bitmap. */
    Dimension left_bitmap_height;
    Dimension right_bitmap_width;
    Dimension right_bitmap_height;
```

```
} SmeBSBprPart;

/*********************************************************************
 *
 * Full instance record declaration
 *
 *********************************************************************/

typedef struct _SmeBSBprRec {
  ObjectPart      object;
  RectObjPart     rectangle;
  SmePart         sme;
  SmeBSBprPart    sme_bsb;
} SmeBSBprRec;

/*****************************************************************
 *
 * Private declarations.
 *
 *****************************************************************/

#endif /* _XawSmeBSBPpr_h */
```

include/xwave.h

```
#include    <X11/Xlib.h>
#include    <X11/Xutil.h>
#include    <X11/Xatom.h>
#include    <X11/Xaw/Cardinals.h>
#include    <X11/StringDefs.h>
#include    <X11/Xmu/Xmu.h>
#include    <X11/Xaw/Command.h>
#include    <X11/Xaw/List.h>
#include    <X11/Xaw/Box.h>
#include    <X11/Xaw/Form.h>
#include    <X11/Xaw/Scrollbar.h>
#include    <X11/Xaw/Viewport.h>
#include    <X11/Xaw/AsciiText.h>
#include    <X11/Xaw/Dialog.h>
#include    <X11/Xaw/MenuButton.h>
#include    <X11/Xaw/SimpleMenu.h>
#include    <X11/Xaw/SmeBSB.h>
#include    <X11/Xaw/Toggle.h>
#include    "SmeBSBpr.h"
#include    "PullRightMenu.h"
#include    <X11/Shell.h>
#include    <X11/cursorfont.h>
#define     STRLEN      100
#define     NAME_LEN  20
#include    "Image.h"
#include    "Message.h"
#include    <dirent.h>
#include    <math.h>
```

```
#include <stdio.h>
#include "Palette.h"
#include "Icon.h"

#define PLOT_DIR "graphs"
#define PLOT_EXT ".plot"
#define ELLA_IN_DIR "."
#define ELLA_IN_EXT ".eli"
#define ELLA_OUT_DIR "."
#define ELLA_OUT_EXT ".elo"
#define VID_DIR "videos"
#define VID_EXT ".vid"
#define IMAGE_DIR "images"
#define BATCH_DIR "batch"
#define BATCH_EXT ".bat"
#define KLICS_DIR "import"
#define KLICS_EXT ".klics"
#define KLICS_SA_DIR "import"
#define KLICS_SA_EXT ".klicsSA"

typedef enum {
	TRANS_None, TRANS_Wave,
} TransType;

typedef enum {
	MONO, RGB, YUV,
} VideoFormat;

extern String ChannelName[3][4];

#define negif(bool,value) ((bool)?-(value):(value))
```

```
typedef struct {
        String name;
        Pixmap pixmap;
        unsigned int height, width;
} IconRec, *Icon;

typedef void (*Proc)();
typedef String *(*ListProc)();
typedef Boolean (*BoolProc)();

typedef struct {
        String name;
        WidgetClass widgetClass;
        String label;
        String hook; /* menuName for smeBSBprObjectClass */
} MenuItem;

typedef struct {
        String name, button;
        ListProc list_proc;
        String action_name;
        Proc action_proc;
        caddr_t action_closure;
} SelectItem, *Selection;

typedef struct {
        TransType type;
        int space[2];
        Boolean dirn;
} WaveletTrans;

typedef union {
```

```
	TransType	type;
	WaveletTrans		wavelet;
} VideoTrans;

typedef	struct _VideoRec	{
	char	name[STRLEN];		/* Name of this video name.vid */
	char	path[STRLEN];			/* Path to frame file(s) */
	char	files[STRLEN];		/* Name of frames files001 if not name */
	VideoFormat type;		/* Type of video (MONO,RGB,YUV) */
	Boolean		disk;	/* Frames reside on disk rather than in memory */
	Boolean		gamma;			/* Gamma corrected flag */
	Boolean		negative;		/* Load negative values in data */
	int	rate;				/* Frames per second */
	int	start;			/* Starting frame number */
	int	size[3];	/* Dimensions of video after extraction x, y and z */
	int	UVsample[2];		/* Chrominance sub-sampling x and y */
	int	offset;			/* Header length */
	int	cols, rows;		/* Dimensions of video as stored */
	int	x_offset, y_offset;	/* Offset of extracted video in stored */
	VideoTrans	trans;			/* Transform technique used */
	int	precision;		/* Storage precision above 8 bits */
	short	**data[3];			/* Image data channels */
	struct _VideoRec	*next;		/* Next video in list */
} VideoRec, *Video;

typedef	struct {
	Video	video;
	char	name[STRLEN];
} VideoCtrlRec, *VideoCtrl;

typedef	struct _PointRec	{
	int	location[2];
```

```
	int	usage;
	struct _PointRec	*next;
} PointRec, *Point;

typedef	struct _FrameRec	{
	Widget	shell, image_widget, point_merge_widget;
	Video video;
	int	zoom, frame, channel, palette;
	Boolean	point_switch, point_merge;
	Point point;
	Message	msg;
	struct _FrameRec	*next;
} FrameRec, *Frame;

#define	NO_CMAPS 6

typedef	struct _BatchRec	{
	Proc proc;
	caddr_t	closure, call_data;
	struct _BatchRec	*next;
} BatchRec, *Batch;

typedef	struct {
	char home[STRLEN];
	XtAppContext	app_con;
	Widget	toplevel;
	int	no_icons;
	Icon	icons;
	Video videos;
	Frame frames;
	Point points;
	Palette	palettes;
```

```
	int	no_pals;
	String	parse_file;
	String	parse_token;
	FILE	*parse_fp;
	XVisualInfo	*visinfo;
	int	levels, rgb_levels, yuv_levels[3];
	Colormap	cmaps[NO_CMAPS];
	String	batch;
	Batch	batch_list;
	Boolean	debug;
	int	dither[16][16];
} GlobalRec, *Global;

typedef	struct {
	Widget	widgets[3];
	int	max, min, *value;
	String	format;
} NumInputRec, *NumInput;

typedef	struct {
	Widget	widgets[2];
	double	max, min, *value;
	String	format;
} FloatInputRec, *FloatInput;

extern Global	global;

/* InitFrame.c */

extern Video	FindVideo();

/* Pop2.c */
```

```
extern void    NA();
extern Widget        FindWidget();
extern void    Destroy();
extern void    Free();

/* Storage.c */

extern void    NewFrame();
extern void    GetFrame();
extern void    SaveFrame();
extern void    FreeFrame();
extern void    SaveHeader();
extern Video CopyHeader();

/* Message.c */

extern void    TextSize();
extern Message        NewMessage();
extern void    MessageWindow();
extern void    CloseMessage();
extern void    Mprintf();
extern void    Dprintf();
extern void    Eprintf();
extern void    Mflush();

/* Icon3.c */

extern void    FillForm();
extern void    FillMenu();
extern Widget        ShellWidget();
extern Widget        FormatWidget();
extern void    SimpleMenu();
```

```
extern int      TextWidth();
extern Icon     FindIcon();
extern void     NumIncDec();
extern void     FloatIncDec();
extern void     ChangeYN();
extern XFontStruct   *FindFont();
```

DATA COMPRESSION AND DECOMPRESSION

GREGORY KNOWLES AND ADRIAN S. LEWIS

M-2357 US

APPENDIX B-1

```
MAC ADDR_COUNTER_COL = (bool:ck,t_reset:reset,STRING[xsize]bit:block_cnt_length)
->
(t_col,bool):
BEGIN
MAKE   BASE_COUNTER_COL:base_counter_col.
JOIN    (ck,reset,block_cnt_length)        ->base_counter_col.

OUTPUT (base_counter_col[1], CASE base_counter_col[2]
                              OF            count_carry:t
                              ELSE f
                              ESAC)
END.

MAC ADDR_COUNTER_ROW = (bool:ck,t_reset:reset,STRING[ysize]bit:block_cnt_length,bool:col_carry)
                              ->
                              (t_row,bool):
BEGIN
MAKE   BASE_COUNTER_ROW:base_counter_row.
JOIN    (ck,reset,col_carry,block_cnt_length,CASE col_carry        #type conversion#
                                    OF t:count_carry
                                    ELSE count_rst
                                    ESAC)    ->base_counter_row.

OUTPUT (base_counter_row[1],  CASE base_counter_row[2]
                    OF       count_carry:t
                    ELSE f
                    ESAC)

END.

#the string base address calculators#
```

```
MAC NOMULT_MAC_READ = (bool:ck,t_reset:reset,bool:col_end,t_mux4:mux_control,STRING[17]bit:incr,
        STRING[17]bit:oct_add_factor, STRING[19]bit:base_u base_v)
        ->
        STRING[19]bit:
BEGIN
MAKE  ADD_US_ACTEL{19,17}:add,
        MUX_2{STRING[17]bit}:mux.

LET
   next_addr = MUX_4{STRING[19]bit}(add[2..20],ZERO{19}b"0",base_u,base_v,mux_control),
        dff = DFF_NO_LOAD{STRING[19]bit}(ck,reset,next_addr,b"0000000000000000000").


JOIN    (dff,mux,b'1)      ->add,
        (incr,oct_add_factor,CASE col_end
                             OF   t:right
                             ELSE left
                             ESAC)                ->mux.
OUTPUT        dff
END.

MAC S_SPA =(STRING[19]bit:in)
->
                          (flag,t_sparc_addr):BIOP TRANSFORM_US.
MAC SPA_S =(t_sparc_addr:in)
->
                          (flag,STRING[19]bit):BIOP TRANSFORM_US.


MAC SPARC_ADDR= (bool:ck,t_reset:reset,bool:col_end,t_mux4:mux_control,[2]t_sparc_addr:oct_add_factor,
```

```
        STRING[19]bit:base_u base_v)
                                ->
                                        t_sparc_addr:
BEGIN
LET out=NOMULT_MAC_READ(ck,reset,col_end,mux_control,(SPA_S oct_add_factor[1])[2][3..19],
                (SPA_S oct_add_factor[2])[2][3..19],base_u,base_v).
OUTPUT  (S_SPA out)[2]
END.


#------------------------------------------------------------------------------#


#the read and write address generator,input the initial image & block sizes for oct/0 at that channel#
FN ADDR_GEN_NOSCRATCH= (bool:ck,t_reset:reset,t_direction:direction,t_channel:channel,
    STRING[9]bit:x_p_1,STRING[11]bit:x3_p_1,STRING[12]bit:x7_p_1,
        STRING [ysize]bit:octave_row_length,STRING [xsize]bit:octave_col_length,t_reset:octave_reset,
        t_octave:octave,bool:y_done,bool:uv_done, t_load:octave_finished, STRING [19]bit:base_u base_v)

                ->
        ((t_input_mux,t_sparcport,t_dwtport#dwt#),t_load#IDWT data valid#,t_load#read_valid#
                ,t_count_control#row read col read#,(t_col,t_count_control)#addr_col_read#):
#the current octave and when the block finishes the 3 octave transform#
BEGIN

#    ADDR_COUNTER_ROW:addr_row_write,#
#        ADDR_COUNTER_COL:addr_col_write,#
MAKE      ROW_COUNT_CARRY:addr_row_read,
          COL_COUNT:        addr_col_read,
          SPARC_ADDR:write_addr read_addr,
        MEM_CONTROL_NOSCRATCH:mem_control,
```

```
        JKFF:zero_hh_bool read_done_bool.          #write begins #

LET    mem_sel                    = CASE octave
                          OF      oct/0:uno,
                                  oct/1:dos,
                                  oct/2:tres,
                                  oct/3:quatro
                          ESAC,

    sparc_add_1             = MUX_4{t_sparc_addr}(
                             (addr/1),
                             (addr/2),
                             (addr/4),
                             (addr/8),
                             mem_sel),

    sparc_add_2_y        = MUX_4{STRING[12]bit}(
                  (b"000000000001"),
                  (b"000" CONC x_p_1[1..7] CONC b"10" ),
                  (b"0" CONC x3_p_1[1..8] CONC b"100" ),
                  (x7_p_1[1..8] CONC b"1000" ),
                             mem_sel),

   sparc_add_2_uv        = MUX_4{STRING[12]bit}(
                  (b"000000000001"),
                  (b"0000" CONC x_p_1[1..6] CONC b"10"),
                  (b"00" CONC x3_p_1[1..7] CONC b"100"),
                  (b"0" CONC x7_p_1[1..7] CONC b"1000"),
                  mem_sel),

    sparc_add_2              = MUX_2{STRING[12]bit}( sparc_add_2_y, sparc_add_2_uv, CASE channel
```

```
                                                          OF     y:left
                                                          ELSE   right
                                                          ESAC),

    sparc_oct_add_factor = (sparc_add_1,(S_SPA( b"0000000" CONC sparc_add_2))[2]).


#signals when write must start  delayed 1 tu for use in zero_hh#

  addr_col_read_flag =CASE addr_col_read[2]#decode to bool#
                OF  count_carry:t
                ELSE f
                ESAC,

  write_latency = CASE (addr_row_read[1], addr_col_read[1])
                  OF    (row/2,col/(conv2d_latency-1)):t
                     ELSE f
           ESAC,

    read_done = CASE (addr_row_read[2], addr_col_read_flag)        #read input data done#
                     OF    (count_carry,t):t
                     ELSE f
                     ESAC,

    zero_hh = CAST{t_load}(NOT zero_hh_bool),

    read_valid= CAST{t_load}(NOT read_done_bool),

    start_write_col= DFF_NO_LOAD{t_load}(ck,reset,zero_hh,read),        #1 tu after zero_hh#
```

```
read_mux =      CASE  (y_done,uv_done,octave_finished,channel)
                OF      (t,f,write,y)|(f,f,write,u):tres,        #base_u#
                        (f,t,write,u)|(f,f,write,v):quatro,     #base v#
                        (f,bool,write,y):dos                              #base y#
                ELSE   uno
                ESAC,

write_mux =    CASE  zero_hh
         OF    write: uno,
                 read:        CASE channel
                              OF      y:dos,           #base y#
                                      u:tres,          #base_u#
                                      v:quatro         #base v#
                              ESAC
                ESAC

JOIN
#note that all the counters have to be reset at the end of an octave, ie on octave_finished#
    (ck,octave_reset,octave_col_length)   ->addr_col_read,        #the row&col counts for the read address#
    (ck,octave_reset,octave_row_length,addr_col_read[2])          ->addr_row_read,


      (ck,octave_reset,write_latency,t) ->zero_hh_bool,

      (ck,octave_reset,read_done,t)              ->read_done_bool,

#w&r addresses for sparc mem#
    (ck,reset,PDF1{bool,conv2d_latency-1}(ck,reset,addr_col_read_flag ,f) ,write_mux,sparc_oct_add_factor,base_u,base_v)
              ->write_addr,
```

```
        (ck,reset,addr_col_read_flag,read_mux,sparc_oct_add_factor,base_u,base_v)      ->read_addr,

        (ck,reset,direction,channel,octave,write_addr,read_addr,zero_hh)->mem_control.

OUTPUT( mem_control,zero_hh, read_valid,addr_row_read[2],addr_col_read)
END.
#the basic 2d convolver for transform, rows first then cols.#
FN CONV_2D = (bool:ck,t_reset:reset, t_input:in, t_direction:direction, [4]t_scratch:pdel,
        t_reset:conv_reset,t_count_control:row_flag,(t_col,t_count_control):addr_col_read)
                        ->
                (t_input,t_memport,t_count_control,t_count_control,t_count_control):

#forward direction outputs in row form      #
#       HH HG HH HG .....                   #
#       HG GG HG GG.....                    #
#       HH HG HH HG .....                   #
#       HG GG HG GG.....                    #
#the inverse convolver returns the raster scan format output data#
#the convolver automatically returns a 3 octave transform#

BEGIN
        FN CH_PORT = (([4]t_scratch,t_col),t_col)
        ->
                t_memport:REFORM.

MAKE    CONV_ROW:conv_row,
        CONV_COL:conv_col.

LET
```

```
row_reset =    CASE direction
        OF   forward:conv_reset,
           inverse: PDF1{t_reset,1}(ck,no_rst,conv_reset,rst)       #pipeline delays in col_conv#
        ESAC,
   col_reset =      CASE direction
                    OF   forward:PDF1{t_reset,3}(ck,no_rst,conv_reset,rst),
                       inverse: conv_reset                     #pipeline delays in row_conv#
                    ESAC,

col_flag = DFM{t_count_control}(ck,addr_col_read[2],PDF1{t_count_control,1}(ck,reset,addr_col_read[2],
                           count_0), CAST{bool}direction),

row_control = DFM{t_count_control}(ck,PDF1{t_count_control,3}(ck,reset,row_flag,count_0),
                           row_flag, CAST{bool}direction),

 direction_sel =CASE direction        #mux control for the in/out data mux's#
        OF    forward:left,
           inverse:right
        ESAC,

   col_count = MUX_2{(t_col,t_count_control)}(
                    PDF1{(t_col,t_count_control),3}(ck,reset,addr_col_read,(col/0,count_rst)),
                    addr_col_read,
                    direction_sel),

#pipeline delays for the convolver values and input value#
     del_conv_col=DFF_NO_LOAD{t_input}(ck,reset,conv_col[1],input/0),

     del_conv_row=DFF_NO_LOAD{t_input}(ck,reset,conv_row,input/0),

     del_in = DFF_NO_LOAD{t_input}(ck,reset,in,input/0).
```

```
JOIN

(ck,row_reset,direction,MUX_2{t_input}(del_in,del_conv_col,direction_sel), col_flag)    ->conv_row,

(ck,col_reset,direction,MUX_2{t_input}(del_conv_row,del_in,direction_sel), pdel,row_control,col_count) ->conv_col.


OUTPUT  (MUX_2{t_input}(del_conv_col,del_conv_row, direction_sel) ,CH_PORT(conv_col[2],col_count[1]),row_control,col_count[2],col_flag)
END.

# 1d col convolver, with control #

FN CONV_COL = (bool:ck,t_reset:reset, t_direction:direction, t_input:in,
[4]t_scratch:pdel,t_count_control:row_flag,
(t_col,t_count_control):col_count)
                                ->
          (t_input,([4]t_scratch,t_col)):

#input is data in and, pdel, out from line-delay memories#
# out is (G,H), and line delay out port.  The row counter is started 1 cycle later to allow for#
#pipeline delay between MULTIPLIER and this unit #

BEGIN
# a %2 line by line resetable counter for the state machines, out->one on rst#
#carry active on last element of row#
   MAC COUNT_2 = (bool:ck,t_reset:reset,t_count_control:carry)
                                ->
                                        t_count_2:
   BEGIN
```

```
      MAKE DFF_NO_LOAD{t_count_2}:countdel.
   LET    countout= CASE (countdel,carry)
               OF     (one,count_carry):two,
                      (two,count_carry):one
               ELSE countdel
               ESAC.
   JOIN   (ck,reset,countout,one)    ->countdel.
   OUTPUT  countdel
   END.


#the code for the convolver#
MAKE  MULT_ADD:mult_add,
      [4]DF1{t_scratch}:pdel_in,
      [4]DF1{t_scratch}:pdel_out,
      COUNT_2:count.

# now the state machines to control the convolver#
#First the and gates#

LET
      reset_row=DF1{t_reset}(ck,reset),          #starts row counter 1 cycle after frame start#
#we want the row counter to be 1 cycle behind the col counter for the delay for the#
#pipelined line delay memory#

col_carry =DFF_NO_LOAD{t_count_control}(ck,reset,col_count[2],count_rst),

#these need to be synchronised to keep the row counter aligned with the data stream#
#also the delay on col_count deglitches the col carryout#

      row_control=row_flag,            #signal for row=0,1,2,3, last row, etc#
```

```
andsel=(CASE direction
        OF      forward: CASE count
                                OF      one:pass,
                                        two:zero
                        ESAC,
                inverse: CASE count
                        OF      one:zero,
                                two:pass
                        ESAC
        ESAC,

        CASE row_control
        OF count_0:zero
        ELSE pass
        ESAC,

        CASE direction
        OF      forward: CASE row_control
                        OF count_0:zero
                        ELSE pass
                        ESAC,
                inverse: pass
        ESAC),
#now the add/sub control for the convolver adders#
    addsel= CASE count
        OF one:(add,add,add,sub),
          two:(add,sub,add,add)
        ESAC,
```

```
#now the mux control#
        centermuxsel=           CASE direction
                                OF      forward: CASE count
                                                        OF one:(left,right),
                                                          two:(right,left)
                                                 ESAC,
                                        inverse:CASE count
                                                 OF     one:(right,left),
                                                        two:(left,right)
                                                 ESAC
                                ESAC,
#the perfect reconstruction output#
#the addmuxsel signal#
        muxandsel =             CASE direction
                                OF      forward:(andsel[2],pass,andsel[2]),
                                        inverse:(pass,andsel[2], CASE row_control
                                                                OF      count_1:zero
                                                                ELSE    pass
                                                                ESAC)
                                ESAC,
        muxsel=         CASE direction
                OF      forward:(uno,

                                CASE row_control
                                OF count_0:dos,
                                  count_carry:tres
                                ELSE uno
                                ESAC,

                                CASE row_control
                                OF count_0:tres,
```

```
                    count_carry:quatro
                  ELSE dos
                  ESAC).

            inverse:( CASE row_control
                  OF count_0:dos,
                    count_1:quatro,
                    count_carry:dos,
                    count_lm1:tres
                  ELSE dos
                  ESAC,

                  CASE row_control
                  OF count_0:tres,
                    count_carry:dos
                  ELSE uno
                  ESAC,

                  uno)
          ESAC.
LET
#ACTEL#
    wr_addr        =DF1{t_col}(ck,DF1{t_col}(ck,col_count[1]) ).
                                      #need 2 delays between wr and rd addr#
    rd_addr=col_count[1].             #address for line delay memory#


#join the control signals to the mult_add block#
JOIN    (ck,reset_row,col_carry) ->count,

    (ck,reset,in,andsel,centermuxsel,muxsel,muxandsel,addsel,direction,pdel_out)     ->mult_add.
```

```
FOR INT k=1..4 JOIN
        (ck,mult_add[k]) ->pdel_in[k],      #delay to catch the write address#
        (ck,pdel[k])        ->pdel_out[k].              #read delay to match MULT delay#

#ACTEL HACK#
LET gh_select =    CASE (direction,DF1{t_count_2}(ck,count) )
          OF      (inverse,one)|(forward,two):right,
               (inverse,two)|(forward,one):left
          ESAC,

  gh_out = MUX_2{t_scratch}(pdel_in[4],DF1{t_scratch}(ck,pdel_out[1]),gh_select),
  shift_const= CASE direction
      OF   inverse:      CASE DF1{t_count_control}(ck,row_control)
                      OF     (count_1 | count_2):shift3
                      ELSE   shift4
                      ESAC,
         forward:      shift5
         ESAC.
OUTPUT  (ROUND_BITS(gh_out,shift_const),(pdel_in,wr_addr#rd_addr#))          #LOCAMII#
END.
#the 1d convolver, with control and coeff extend#


FN CONV_ROW =(bool:ck,t_reset:reset,t_direction:direction,t_input:in, t_count_control:col_flag)
                                   ->
                                                t_input:
# out is (G,H).  The row counter is started 1 cycle later to allow for#
#pipeline delay between MULTIPLIER and this unit #
#the strings give the col & row lengths for this octave#
```

```
BEGIN
        # a %2 line by line resetable counter for the state machines, out->one on rst#

        MAC COUNT_2 = (bool:ck,t_reset:reset)
                                                ->
                                                      t_count_2:
        BEGIN
                MAKE DFF_NO_LOAD(t_count_2):countdel.
        LET     countout= CASE (countdel)
                          OF     (one):two,
                                 (two):one
                          ESAC.
        JOIN    (ck,reset,countout,one)  ->countdel.
        OUTPUT          countdel
        END.

#the code for the convolver#
MAKE  MULT_ADD:mult_add,
        [4]DF1{t_scratch}:pdel,
        COUNT_2:count.

# now the state machines to control the convolver#
#First the and gates#

LET

        reset_col=DF1{t_reset}(ck,reset),         #starts row counter 1 cycle after frame start#
                                        #makes up for the pipeline delay in MULT#
#!!!LATENCY DEOENDENT!!#
        col_control=col_flag,           #flag when col_count=0,1,2,col_length,etc#
```

```
andsel=(CASE direction
        OF      forward: CASE count
                                OF      one:pass,
                                        two:zero
                        ESAC,
                inverse: CASE count
                        OF      one:zero,
                                two:pass
                        ESAC
        ESAC,

         CASE col_control
        OF count_0:zero
        ELSE pass
        ESAC,

        CASE direction
        OF      forward: CASE col_control
                        OF count_0:zero
                        ELSE pass
                        ESAC,
                inverse: pass
        ESAC),
#now the add/sub control for the convolver adders#
    addsel= CASE count
        OF one:(add,add,add,sub),
          two: (add,sub,add,add)
        ESAC,

#now the mux control#
```

```
centermuxsel=          CASE direction
                       OF     forward: CASE count
                                          OF one:(left,right),
                                            two:(right,left)
                                   ESAC,
                              inverse:CASE count
                                   OF     one:(right,left),
                                          two:(left,right)
                                   ESAC
                       ESAC,
#the addmuxsel signal#
        muxandsel =    CASE direction
                       OF     forward:(andsel[2],pass,andsel[2]),
                              inverse:(pass,andsel[2], CASE col_control
                                                       OF     count_1:zero
                                                       ELSE   pass
                                                       ESAC)
                       ESAC,
        muxsel=    CASE direction
              OF   forward:(uno,

                       CASE col_control
                       OF count_0:dos,
                         count_carry:tres
                       ELSE uno
                       ESAC,

                       CASE col_control
                       OF count_0:tres,
                         count_carry:quatro
                       ELSE dos
```

```
                    ESAC),

                inverse:( CASE col_control
                    OF count_0:dos,
                       count_1:quatro,
                       count_lm1:tres
                    ELSE dos
                    ESAC,

                    CASE col_control
                    OF count_0:tres,
                       count_carry:dos
                    ELSE uno
                    ESAC,

                    uno)
            ESAC.

#join the control signals to the mult_add block#
JOIN    (ck,reset_col)    ->count,
#set up the col counters #
        (ck,reset,in,andsel,centermuxsel,muxsel,muxandsel,addsel,direction,pdel)->mult_add.

FOR INT j=1..4 JOIN
            (ck,mult_add[j])  ->pdel[j].        #pipeline delay for mult-add unit#

#ACTEL HACK#
LET     gh_select=CASE direction
           OF    inverse:     CASE count
                       OF    one: left,
```

```
                     two: right
                 ESAC,
       forward:      CASE count
                  OF    one:right,
                        two:left
                 ESAC
    ESAC,

    gh_out = MUX_2{t_scratch}(pdel[4],DF1{t_scratch}(ck, pdel[1]),gh_select),

  rb_select=  CASE direction
     OF      inverse:CASE col_control
                      OF      (count_2 | count_3):shift3
                      ELSE  shift4
                      ESAC,
             forward:         shift5
             ESAC.
OUTPUT ROUND_BITS(gh_out,rb_select)
END.


#some string macros#
MAC EQ_US = (STRING[INT n]bit: a b)
                      ->
                          bool: BIOP EQ_US.

#ACTEL 8 bit comparitor macro#
FN ICMP8 = (STRING[8]bit: a b)
                      ->
                          bool: EQ_US{8}(a,b).
```

```
#..............................................................#
#A set of boolean ,ie gate level counters                      #
#..............................................................#

#..............................................................#
#The basic toggle flip-flop plus and gate for a synchronous counter  #
#input t is the toggle ,outputs are q and tc (toggle for next counter#
#stage                                                               #
#..............................................................#

MAC  BASIC_COUNT = (bool:ck ,t_reset:reset,bool: tog)
                                                        ->
                                                        [2]bool:

BEGIN
            MAKE DFF_NO_LOAD{bool}:dlat,
                  XOR   :xor,
                  AND   :and.

            JOIN  (ck,reset,xor,f)->dlat,
                  (dlat,tog)   ->and,
                  (tog,dlat)   ->xor.
            OUTPUT (dlat,and)
END.

#..............................................................#
# The n-bit macro counter generator, en is the enable, the outputs   #
#are msb(bit 1).....lsb,carry.This is the same order as ELLA strings are stored#
#..............................................................#

MAC COUNT_SYNC{INT n} = (bool:ck,t_reset: reset,bool: en )
```

```
                                        ->
                                                   ([n]bool,bool):
(LET out = BASIC_COUNT(ck,reset,en) .

        OUTPUT      IF n=1
                THEN   ([1]out[1],out[2])
                ELSE ( LET outn = COUNT_SYNC{n-1}(ck,reset,out[2]) .
                        OUTPUT (outn[1] CONC out[1],outn[2])
                )
                FI
).

#a mod 2^xsize counter#
MAC MOD2_COUNTER_COL = (bool:ck,t_reset:reset)
                                              ->
                                                      (t_col):
BEGIN
        MAC S_TO_C  = (STRING[xsize]bit:in)
                                              ->
                                                      (flag,t_col):BIOP TRANSFORM_US.
        MAKE COUNT_SYNC{xsize}:count,
           BOOL_STRING{xsize}:b_s.

JOIN    (ck,reset,t)       ->count,        #count always enabled#
        count[1]->b_s.
OUTPUT (S_TO_C b_s)[2]
END.


#a mod 2^ysize counter#
MAC MOD2_COUNTER_ROW = (bool:ck,t_reset:reset,bool:en)
```

```
                                              ->
                                                   (t_row):
BEGIN
   MAC S_TO_R  = (STRING[ysize]bit:in)
                                         ->
                                              (flag,t_row):BIOP TRANSFORM_US.
   MAKE COUNT_SYNC{ysize}:count,
     BOOL_STRING{ysize}:b_s.

JOIN   (ck,reset,en)   ->count,
   count[1]      ->b_s.
OUTPUT (S_TO_R b_s)[2]
END.

#the basic mod col_length counter, to be synthesised#
MAC BASE_COUNTER_COL = (bool:ck,t_reset:reset,STRING[xsize]bit:octave_cnt_length)
                                                              ->
                                                              (t_col,t_count_control):
BEGIN

     MAC C_TO_S = (t_col: in)
                                   ->
                                         (flag,STRING[xsize]bit): BIOP TRANSFORM_US.
   MAC FINAL_COUNT = (t_col:in,STRING[xsize]bit:octave_cnt_length)
                                   ->
                              t_count_control:
   BEGIN
   LET    in_us =  (C_TO_S in)[2],
      lsb=in_us[xsize].
   #OUTPUT CASE EQ_US(in_us[1..xsize-1],octave_cnt_length[1..xsize-1])  the msb's are the same#
#ACTEL#
```

```
    OUTPUT CASE ICMP8(in_us[1..xsize-1],octave_cnt_length[1..xsize-1])  #the msb's are the same#
       OF  t: CASE lsb              #so check the lsb#
          OF b'1:count_carry,     #count odd, so  must be length#
            b'0:count_lm1        #count is even so must be length-1#
          ESAC
       ELSE count_rst
       ESAC
     END.
MAKE  MOD2_COUNTER_COL:mod2_count,
      FINAL_COUNT:final_count.

JOIN  (mod2_count,octave_cnt_length)          ->final_count,
      (ck,CASE reset                                   #system reset or delayed carryout reset#
        OF    rst: rst
        ELSECASE DFF_NO_LOAD{t_count_control}(ck,reset,final_count,count_0)  #latch to avoid glitches#
                     OF       count_carry:rst
                     ELSE no_rst
                     ESAC
        ESAC)                                          ->mod2_count.
OUTPUT (mod2_count,final_count)
END.


FN COL_COUNT_ST = (bool:ck,t_reset:reset,STRING[xsize]bit:octave_cnt_length)
                                                       ->
                                               (t_col,t_count_control):
                                       #count value , and flag for count=0,1,2,col_length-1, col_length#
BEGIN
      MAKE BASE_COUNTER_COL:base_col.

LET     count_control = CASE reset
```

```
                OF  rst:count_0
                        ELSE CASE base_col[1]
                        OF      col/0:count_0,
                                col/1:count_1,
                                col/2:count_2,
                                col/3:count_3

                                ELSE   base_col[2]
                                ESAC
                ESAC.
  JOIN (ck, reset,octave_cnt_length)     ->base_col.
  OUTPUT       (base_col[1],count_control)
END.


#the basic mod row_length counter, to be synthesised#
MAC BASE_COUNTER_ROW = (bool:ck,t_reset:reset,bool:en,STRING[ysize]bit:octave_cnt_length,t_count_control:col_carry)
                                        ->
                                        (t_row,t_count_control):
BEGIN

    MAC R_TO_S = (t_row: in)
                                    ->
                                        (flag,STRING[ysize]bit): BIOP TRANSFORM_US.
    MAC FINAL_COUNT = (t_row:in,STRING[ysize]bit:octave_cnt_length)
                                             ->
                                                  t_count_control:
    BEGIN
    LET    in_us =  (R_TO_S in)[2],
         lsb=in_us[ysize].
    #OUTPUT CASE EQ_US(in_us[1..ysize-1],octave_cnt_length[1..ysize-1])  the msb's are the same#
```

```
#ACTEL#
    OUTPUT CASE ICMP8(in_us[1..ysize-1],octave_cnt_length[1..ysize-1])  #the msb's are the same#
        OF  1: CASE lsb              #so check the lsb#
            OF b'1:count_carry,    #count odd, so  must be length#
              b'0:count_lm1        #count is even so must be length-1#
            ESAC
        ELSE count_rst
        ESAC
    END.
MAKE   MOD2_COUNTER_ROW:mod2_count,
     FINAL_COUNT:final_count.

#need to delay the reset at end of count signal till end of final row#
#WAS DFF WITH reset#
LET  count_reset =DF1{t_reset}(ck,CASE(final_count,col_carry)   #last row/last col#
                                    OF (count_carry,count_carry):rst #latch to avoid glitches#
                                    ELSE no_rst
                                    ESAC).

JOIN    (mod2_count,octave_cnt_length)  ->final_count,
      (ck,CASE reset                    #system reset or delayed carryout reset#
        OF   rst: rst
        ELSE      count_reset
        ESAC,en)                ->mod2_count.
OUTPUT (mod2_count,final_count)
END.

FN ROW_COUNT_CARRY_ST = (bool:ck,t_reset:reset,STRING[ysize]bit:octave_cnt_length,t_count_control:col_carry)
                              ->
                         (t_row,t_count_control):
```

```
BEGIN
      MAKE BASE_COUNTER_ROW:base_row.
LET   count_control = CASE reset
           OF rst:count_0
              ELSE CASE base_row[1]
              OF    row/0:count_0,
                 row/1:count_1,
                 row/2:count_2,
                 row/3:count_3

                 ELSE   base_row[2]
                 ESAC
           ESAC.

  JOIN (ck,reset,CASE col_carry
             OF count_carry:t
             ELSE f
             ESAC,octave_cnt_length,col_carry)    ->base_row.
  OUTPUT   (base_row[1],count_control)
 END.

#the discrete wavelet transform chip/ multi-octave/2d transform with edge compensation#
#when ext & csl are both low latch the setup params from the nubus(active low), as follows#
#adl[1..4]       select function#
#       0000   load max_octaves, luminance/colour, forward/inversebar#
#       0001   load yimage#
#       0010   load ximage#
#jump table values#
#       0011   load ximage+1#
#       0100   load 3ximage+3#
#       0101   load 7ximage+7#
```

```
#       0110    load base u addr#
#       0111    load base v addr#

#adl[21..22]    max_octaves#
#adl[23]luminance/crominancebar active low, 1 is luminance,0 is colour#
#adl[24]forward/inversebar active low, 1 is forward, 0 is inverse#

#adl[5..24]     data (bit 24 lsb)#

FN ST_OCT = (STRING[2]bit:st)
->
                        (flag,t_octave): BIOP TRANSFORM_US.

FN OCT_ST = (t_octave:st)
->
                        (flag,STRING[2]bit):BIOP TRANSFORM_US.

FN DWT = (bool:ck_in,t_reset:reset_in, t_input:in_in,bcol:extwritel_in csl_in, STRING[24]bit:adl,
        t_input:sparc_mem_in, [4]t_scratch:pdel_in)


        ->
                (t_input#out IDWT data#,[3]t_load#valid out IDWT data,y,u,v#,
        [3]t_load#valid in DWT data y,u,v#,
        t_sparcport#sparc_data_addr, etc#,
        t_memport#pdel_data_out#):

BEGIN
MAKE CONV_2D:conv_2d,
        ADDR_GEN_NOSCRATCH:addr_gen,
#active low clock &enable latches#
```

```
        [2]DLE1D:max_octave_st,
        DLE1D:channel_factor_st,
        DLE1D:dir,
        [9]DLE1D:col_length_s,
        [9]DLE1D:row_length_s,
        [9]DLE1D:x_p_1,
        [11]DLE1D:x3_p_1,
        [12]DLE1D:x7_p_1,
        [19]DLE1D:base_u,
        [19]DLE1D:base_v,
#active low 3X8 decoder#
        DEC3X8A                  :decodel,
#the octave control#
        DFF_INIT{t_octave}: octave ,
        DFF_INIT{t_channel}: channel ,
        JKFF:row_carry_ff,
#pads#
        INBUF{STRING[24]bit}:adl_out,
        CLKBUF:ck,
        INBUF{bool}:extwritel csl,
        INBUF{t_reset}:reset,
        INBUF{t_input}:in sparc_mem,
        INBUF{[4]t_scratch}:pdel,
        OBHS{t_input}:out1,
        OBHS{[3]t_load}:out2 out3,
        OBHS{t_sparcport}:out4,
        OBHS{t_memport}:out5.
#must delay the write control to match the data output of conv_2d, ie by conv2d_latency#
LET
#set up the control params#
```

```
max_oct = (ST_OCT BOOL_STRING{2}max_octave_st)[2],

channel_factor= CAST{t_channel_factor}channel_factor_st,

col_length =  BOOL_STRING{9} col_length_s,

row_length =  BOOL_STRING{9} row_length_s,

direction =CASE dir
    OF     f:forward,
           t:inverse
    ESAC,

#set up the octave params#
      convcol_row= conv_2d[3],
   convcol_col=conv_2d[4],
   convrow_col=conv_2d[5],
#signals that conv_col, for forward, or conv_row, for inverse, has finished that octave#
#and selects the next octave value and the sub-image sizes#

   octave_finished =CASE direction
            OF     forward:CASE (row_carry_ff,convcol_row,convcol_col)
                      OF  (t,count_2,count_2):write  #row then col, gives write latency#
                      ELSE read
                      ESAC,
                   inverse:CASE (row_carry_ff,convcol_row,convrow_col)
                      OF  (t,count_2,count_3):write  #extra row as col then row#
                      ELSE read
                      ESAC
              ESAC,
 #max octaves for u|v#
```

```
        ESAC;

                    CASE (y_done,uv_done)
                    OF      (t,bool)|(bool,t):new_oct:=oct/0
                    ELSE
                    ESAC
                    ),

inverse:(CASE octave
        OF    oct/3:new_oct:=oct/2,
              oct/2:new_oct:=oct/1,
              oct/1:new_oct:=oct/0
        ESAC;
        CASE channel
        OF    y: CASE octave
                 OF  oct/0:CASE channel_factor #watch for colour#
                                        OF      luminance:new_oct:=max_oct
                                        ELSE              new_oct:=max_oct_1
                                        ESAC
                 ELSE
              ESAC,
              u:CASE octave
                 OF  oct/0:new_oct:=max_oct_1
                 ELSE
                 ESAC,
              v:CASE octave
                 OF  oct/0:new_oct:=max_oct       #move to y#
                 ELSE
                 ESAC
        ESAC)
```

```
ESAC;
          CASE  channel_factor
          OF       luminance:new_channel:=y,
                   color: (CASE (channel,y_done)
          OF   (y,t):new_channel:=u
          ELSE
          ESAC;
          CASE (channel,uv_done)
          OF   (u,t):new_channel:=v,
             (v,t):new_channel:=y
          ELSE
          ESAC)
       ELSE
       ESAC;
   OUTPUT (new_oct,new_channel)
   ),

octave_sel = CASE (octave,channel)    #the block size divides by 2 every octave#
        OF     (oct/0,y):uno,      #the u|v image starts 1/4 size#
            (oct/1,y)|(oct/0,u|v):dos,
            (oct/2,y)|(oct/1,u|v):tres,
            (oct/3,y)|(oct/2,u|v):quatro
             ESAC,
octave_row_length =MUX_4{STRING [ysize]bit}(row_length,b"0" CONC row_length[1..ysize-1],
                 b"00" CONC row_length[1..ysize-2],
                          b"000" CONC row_length[1..ysize-3],octave_sel),
octave_col_length = MUX_4{STRING [xsize]bit}(col_length,b"0" CONC col_length[1..xsize-1],
                 b"00" CONC col_length[1..xsize-2],
                          b"000" CONC col_length[1..xsize-3],octave_sel),
```

```
#load next octave, either on system reset, or write finished#
    load_octave=        CASE reset
                    OF   rst:write
                    ELSE     octave_finished
                     ESAC,
#reset the convolvers at the end of an octave, ready for the next octave#
#latch pulse to clean it, note 2 reset pulses at frame start#
#cant glitch as reset&octave_finished dont change at similar times#
    conv_reset =  CASE reset
                OF  rst:rst
                ELSE   CASE  DFF_NO_LOAD{t_load}(ck,reset, octave_finished,read)
                    OF     write:rst
                    ELSE   no_rst
                    ESAC
                ESAC,


#latch control data off nubus, latch control is active low#
        gl =      CASE (extwritel,csl)
                  OF       (f,f):f
                  ELSE   t
                  ESAC,


        sparc_w=addr_gen[1][2][1],        #write addresses#

        input_mux=addr_gen[1][1],  #input_mux#

        sparc_r=addr_gen[1][2][2],        #read addresses#

        sparc_rw = addr_gen[1][2][3],
```

```
        inverse_out =   CASE (direction,octave)
                        OF      (inverse,oct/0):CASE (channel,addr_gen[2])
                                        OF      (y,write):(write,read,read),
                                                (u,write):(read,write,read),
                                                (v,write):(read,read,write)
                                        ELSE (read,read,read)
                                        ESAC,
                                (forward,oct/0):(read,read,read)
                        ELSE (read,read,read)
                        ESAC,
        forward_in =    CASE direction
                        OF      forward:CASE (channel,octave,addr_gen[3])
                                        OF      (y,oct/0,read):(read,write,write),
                                                (u,oct/0,read):(write,read,write),
                                                (v,oct/0,read):(write,write,read)
                                                ELSE (write,write,write)
                                                ESAC,
                                inverse:(write,write,write)
                        ESAC.
JOIN
#in pads#
        ck_in           ->ck,
        reset_in->reset,
        extwritel_in    ->extwritel,
        csl_in          ->csl,
        adl             ->adl_out,
        in_in           ->in,
        sparc_mem_in    ->sparc_mem,
        pdel_in         ->pdel,
#out pads#
```

```
        conv_2d[1]       ->out1,
        inverse_out      ->out2,
        forward_in       ->out3,
        addr_gen[1][2]   ->out4,
     conv_2d[2] ->out5,

#the control section#
        (CAST{bool}adl[4],CAST{bool}adl[3],CAST{bool}adl[2])    ->decodel,        #active low outs#

        (gl,decodel[1],BIT_BOOLadl_out[21])     ->max_octave_st[1],
        (gl,decodel[1],BIT_BOOLadl_out[22])     ->max_octave_st[2],

        (gl,decodel[1],BIT_BOOLadl_out[23])     ->channel_factor_st,
        (gl,decodel[1],BIT_BOOLadl_out[24])     ->dir.
FOR INT j=1..9 JOIN
        (gl,decodel[2],BIT_BOOLadl_out[15+j])    ->col_length_s[j],
        (gl,decodel[3],BIT_BOOLadl_out[15+j])      ->row_length_s[j],
        (gl,decodel[4],BIT_BOOLadl_out[15+j])      ->x_p_1[j].
FOR INT j=1..11 JOIN
        (gl,decodel[5],BIT_BOOLadl_out[13+j])      ->x3_p_1[j].
FOR INT j=1..12 JOIN
        (gl,decodel[6],BIT_BOOLadl_out[12+j])      ->x7_p_1[j].
FOR INT j=1..19 JOIN
        (gl,decodel[7],BIT_BOOLadl_out[5+j])      ->base_u[j],
        (gl,decodel[8],BIT_BOOLadl_out[5+j])      ->base_v[j].

#sets a flag when row counter moves onto next frame#
JOIN
     (ck,conv_reset,CASE convcol_row
          OF    count_carry:t
          ELSE  f
```

```
    ESAC,t)                          ->row_carry_ff,


#load the new octave,after the current octave has finished writing#
# on initial reset must load with starting octave value which depends on direction and channel#
   (ck,no_rst,load_octave, CASE reset
                    OF  no_rst:next[1]
                    ELSE   CASE (direction,channel)  #initial octave#
                           OF  (forward,t_channel):oct/0,
                               (inverse,y):max_oct,
                               (inverse,u|v):max_oct_1
                          ESAC
                    ESAC,oct/0)              ->octave,  #next octave#
      (ck,no_rst,load_octave, CASE reset
              OF  no_rst:next[2]
                    ELSE  y
                    ESAC,y)              ->channel,  #next channel#

      (ck,reset,MUX_2{t_input}(in,sparc_mem,CASE input_mux  #input_mux#
                                             OF   dwt_in:left,
                                                  sparc_in:right
                                              ESAC)
      ,direction,pdel, conv_reset,addr_gen[4],addr_gen[5])      ->conv_2d,


(ck,reset,direction,channel,BOOL_STRING{9}x_p_1,BOOL_STRING{11}x3_p_1, BOOL_STRING{12}x7_p_1,octave_row_length,
octave_col_length,conv_reset,octave,y_done,uv_done,octave_finished,BOOL_STRING{19}base_u, BOOL_STRING{19}base_v)    ->addr_gen.

OUTPUT        (out1 ,out2,out3,out4,out5)
END.
FN DWT_TEST = (bool:ck_in,t_reset:reset_in, t_input:in_in,bool:extwritel_in csl_in,t_sparc_addr:reg_sel value)
```

```
                          ->
                                        (t_input,[3]t_load,[3]t_load):
BEGIN
   FN SPARC_MEM = (t_input:in,t_sparc_addr:wr_addr,t_sparc_addr:rd_addr,t_load:rw_sparc#,t_cs:cs#)
     ->
          t_input:
         RAM(input/0).

     MAKE  DWT:dwt,
           SPARC_MEM:sparc_mem,
           LINE_DELAY{t_scratch}:line_delay.

LET   data_out=dwt[1],
      sparc_port=dwt[4],
      line_delay_port = dwt[5].
JOIN
      (ck_in,reset_in,in_in,extwritel_in, csl_in,(SPA_S reg_sel)[2][16..19]CONC b"1" CONC(NOT_B (SPA_S value)[2]), sparc_mem,line_delay)
                                        ->dwt,
      (data_out,sparc_port[1],sparc_port[2],sparc_port[3]#,sparc_port[4]#)        ->sparc_mem,

      (line_delay_port[1],line_delay_port[2],line_delay_port[3],write)     ->line_delay.

OUTPUT      dwt[1..3]
END.

# some basic macros for the convolver, assume these will#
#be synthesised into leaf cells#
#the actel MX4 mux cell#
FN NOT = (bool:in)
->
bool:CASE in OF t:f,f:t ESAC.
```

```
MAC  MX_4{TYPE ty}=(ty:in1 in2 in3 in4, [2]bool:sel)
->
                          ty:
CASE   sel
OF       (f,f):in1,
         (f,t):in2,
         (t,f):in3,
         (t,t):in4
ESAC.
#the actel GMX4 mux cell#
MAC  GMX4{TYPE ty}=(ty:in1 in2 in3 in4, [2]bool:sel)
         ->
                 ty:
CASE   sel
OF     (f,f):in1,
      (f,t):in2,
      (t,f):in3,
      (t,t):in4
ESAC.

MAC  MXT{TYPE ty}=(ty:a b c d, bool:soa sob s1)
         ->
         ty:
CASE   s1
OF     f: CASE soa
           OF    t:b
           ELSE  a
           ESAC,
         t: CASE sob
```

```
        OF  t:d
        ELSE  c
        ESAC
ESAC.
MAC ENCODE4_2 = (t_mux4:in)
          ->
          [2]bool:
CASE in
OF        uno:(f,f),
          dos:(f,t),
          tres:(t,f),
          quatro:(t,t)
ESAC.

MAC ENCODE3_2 = (t_mux3:in)
          ->
          [2]bool:
CASE in
OF     l:(f,f),
       c:(f,t),
       r:(t,f)
ESAC.

FN DEC3X8A = (bool:a b c)
->
[8]bool:
CASE (a,b,c)
OF        (f,f,f):(f,t,t,t,t,t,t,t),
          (t,f,f):(t,f,t,t,t,t,t,t),
          (f,t,f):(t,t,f,t,t,t,t,t),
          (t,t,f):(t,t,t,f,t,t,t,t),
```

```
        (f,f,t):(t,t,t,t,f,t,t,t),
        (t,f,t):(t,t,t,t,t,f,t,t),
        (f,t,t):(t,t,t,t,t,t,f,t),
        (t,t,t):(t,t,t,t,t,t,t,f)
ESAC.

MAC MUX_2{TYPE t}=(t:in1 in2, t_mux:sel)
->
t:
CASE sel
OF      left:in1,
        right:in2
ESAC.

MAC MUX_3{TYPE t}=(t:in1 in2 in3 , t_mux3:sel)
->
t:
MX_4{t}(in1,in2,in3,in1,ENCODE3_2 sel).

COM
MAC MUX_4{TYPE t}=(t:in1 in2 in3 in4, t_mux4:sel)
->
t:
CASE sel
OF      uno:in1,
        dos:in2,
        tres:in3,
        quatro:in4
ESAC.
MOC
```

```
MAC  MUX_4{TYPE t}=(t:in1 in2 in3 in4, t_mux4:sel)
->
t:
MX_4{t}(in1,in2,in3,in4,ENCODE4_2 sel).

FN AND2 = (bool:a b)
->
bool:BIOP AND.


MAC GNAND2 = (bool:a b)
->
bool:NOT AND2(a,b).

MAC    AND_2 = (t_scratch:in, t_and:sel)
->
t_scratch:
BEGIN
LET     in_s = (I_TO_S{scratch_exp}in)[2],
        sel_s = CAST{bool}sel.
OUTPUT (S_TO_I{scratch_exp}BOOL_STRING{scratch_exp} ([INT j=1..scratch_exp]AND2(BIT_BOOL in_s[j],sel_s) ))[2]
END.


FN XOR = (bool: a b)
->
bool:
CASE (a,b)
OF  (f,f)|(t,t):f
ELSE t
ESAC.
```

```
MAC XOR_B{INT n} = (STRING[n]bit:a b)
->
STRING[n]bit: BIOP XOR.

MAC NOT_B = (STRING[INT n]bit:a)
->
STRING[n]bit:BIOP NOT.

MAC XNOR_B = (STRING[INT n]bit:a b)
->
STRING[n]bit:
NOT_B XOR_B{n}(a,b).

FN AND = (bool: a b)
->
bool:
CASE (a,b)
OF  (t,t):t
ELSE f
ESAC.

MAC DEL{TYPE t} = (t)
->
t:DELAY(?t,1).

#a general dff same as DFF_NO_LOAD#
MAC DFF {TYPE t}=(bool:ck,t_reset:reset,t:in init_value)
->
t:
BEGIN
```

```
MAKE DEL{t}:del.
JOIN in->del.
OUTPUT CASE reset
      OF rst:init_value
      ELSE   del
      ESAC
END.


#a general dff#
MAC DF1 {TYPE t}=(bool:ck,t:in)
->
t:
BEGIN
MAKE DEL{t}:del.
JOIN in->del.
OUTPUT del
END.

#a general latch#
MAC DL1 {TYPE ty}=(bool:ck,ty:in)
->
ty:
BEGIN
MAKE DEL{ty}:del.
JOIN CASE ck
          OF t:in
          ELSE del
          ESAC   ->del.
OUTPUT CASE ck
          OF t:in
```

```
          ELSE del
          ESAC
END.

#a general d latch#
MAC LATCH {TYPE t}=(bool:ck,t_load:load,t:in)
->
t:
BEGIN
MAKE DEL{t}:del.
LET out=CASE load
      OF    write:in
      ELSE  del
      ESAC.
JOIN out->del.
OUTPUT out
END.

#an ACTEL D LATCH#
MAC DLE1D = (bool:ckl loadl,bool:in)
->
bool:#qn#
NOT LATCH{bool}(NOT ckl, CASE loadl
             OF   t:write
             ELSE read
                    ESAC,  in).

MAC PDF1{TYPE t,INT n} = (bool:ck,t_reset:reset,t:in initial_value)
->
t:
      IF n=0 THEN DFF{t}(ck,reset,in,initial_value)
```

```
    ELSE    PDF1{t,n-1}(ck,reset,DFF{t}(ck,reset, in,initial_value),initial_value)
    FI.


#a muxed input dff#
MAC DFM {TYPE ty}=(bool:ck,ty:a b,bool:s)
->
ty:
BEGIN
MAKE DEL{ty}:del.
JOIN CASE s
        OF f:a,
          t:b
        ESAC    ->del.
OUTPUT del
END.
#a resetable DFF, init value is input parameter#
MAC DFF_INIT{TYPE t}=(bool:ck,t_reset:reset,t_load:load,t:in init_value)
->
t:
BEGIN
MAKE DEL{t}:del.
LET out=CASE (load,reset)
    OF    (write,t_reset):in,
          (read,rst):init_value
    ELSE  del
    ESAC.
JOIN out->del.
OUTPUT CASE reset
    OF rst:init_value
    ELSE    del
```

```
    ESAC
END.

#a resetable JKFF, k input is active low#
FN JKFF=(bool:ck,t_reset:reset,bool:j k)
->
bool:
BEGIN
MAKE DEL{bool}:del.
LET out=CASE (j,k,reset)
    OF   (t,t,no_rst):t,
      (f,t,rst):f,
      (t,f,rst):t,
        (f,f,no_rst):f,
        (f,t,no_rst):del,
        (t,f,no_rst):NOT del
    ESAC.
JOIN out->del.
OUTPUT CASE reset
    OF rst:f
    ELSE   del
    ESAC
END.

#a dff resetable non- loadable dff#
MAC DFF_NO_LOAD{TYPE t}=(bool:ck,t_reset:reset,t:in init_value)
->
t:
BEGIN
MAKE DEL{t}:del.
JOIN in->del.
```

```
OUTPUT CASE reset
      OF rst:init_value
      ELSE   del
      ESAC
END.

MAC PDEL{TYPE t,INT n} = (t:in)
->
t:
      IF n=0 THEN DEL{t}in
      ELSE   PDEL{t,n-1} DEL{t} in
      FI.

#the mem control unit for the DWT chip, outputs the memport values for the sparc, and dwt#
#inputs datain from these 2 ports and mux's it to the 2d convolver.#

MAC MEM_CONTROL_NOSCRATCH = (bool:ck,t_reset:reset,t_direction:direction,t_channel:channel,t_octave:octave,
                              t_sparc_addr:sparc_addr_w sparc_addr_r,t_load:zero_hh)

             ->
                              (t_input_mux,t_sparcport,t_dwtport#dwt#):

BEGIN
#the comb. logic for the control of the i/o ports of the chip#
LET ports = (SEQ

      VAR    #defaults, so ? doesnt kill previous mem value#
         rw_sparc:=read,
         rw_dwt:=read,
         cs_dwt:=no_select,
         input_mux:=sparc_in;
```

```
        CASE (direction,octave)
        OF              (forward,oct/0): ( cs_dwt:=select;
                                           input_mux:=dwt_in),

                        (inverse,oct/0):( CASE zero_hh
                                          OF     write:(rw_dwt:=write;
                                                        cs_dwt:=select)
                                          ELSE
                                          ESAC)
        ESAC;

#rw_sparc=write when ck=1 and zero_hh=write, otherwise = read#
        rw_sparc:= CAST{t_load}GNAND2(NOT CAST{bool}zero_hh,ck);

#mux the sparc addr on clock#
#       sparc_addr = GMX4{t_sparc_addr}(sparc_r,sparc_r,sparc_w,sparc_w,ck,f);#

        OUTPUT (input_mux, (sparc_addr_w,sparc_addr_r,rw_sparc),    #sparc port#
                (rw_dwt,cs_dwt)                          #dwt port#
               )

        ).
OUTPUT ports
END.

# the basic 1d convolver without the control unit#

MAC MULT_ADD = (bool:ck,t_reset: reset,t_input:in, [3]t_and:andsel, [2]t_mux:centermuxsel,[3]t_mux4:muxsel,
                [3]t_and:muxandsel,[4]t_add:addsel, t_direction:direction,[4]t_scratch:pdel)
->
                [4]t_scratch: #pdel are the outputs from the line delays#
```

```
BEGIN

        MAKE   MULTIPLIER:mult,
               [4]ADD_SUB:   add.
#the multiplier outputs#
LET    x3=mult[1],
     x5=mult[2],
     x11=mult[3],
     x19=mult[4],
     x2=mult[5],
     x8=mult[6],
     x30=mult[7],

#the mux outputs#
               mux1=MUX_4{t_scratch}(x11,x5,x8,x2,muxsel[1]),

               mux2=MUX_4{t_scratch}(x19,x30,x8,scratch/0,muxsel[2]),

               mux3=MUX_4{t_scratch}(x11,x5,x8,x2,muxsel[3]),

               centermux=(MUX_2{t_scratch}(pdel[1],pdel[3],centermuxsel[1]),
                          MUX_2{t_scratch}(pdel[2],pdel[4],centermuxsel[2]) ),

               # the AND gates zero the adder inputs every 2nd row#
#the and gate outputs#
               and1=AND_2(pdel[2],andsel[1]),
               and2=AND_2(pdel[3],andsel[1]),
               and3=AND_2(centermux[1],andsel[2]),
               and4=AND_2(centermux[2],andsel[3]),

               add1in=AND_2(mux1,muxandsel[1]),
```

```
            add3in=AND_2(mux3,muxandsel[2]),
            add4in=AND_2(x3,muxandsel[3]).


    JOIN    in          ->mult,
            (and1,add1in,addsel[1]) ->add[1],
            (and3,mux2,addsel[2])   ->add[2],
            (and4,add3in,addsel[3]) ->add[3],
            (and2,add4in,addsel[4]) ->add[4].


    OUTPUT add
END.
# the basic multiplier unit of the convolver #

MAC MULTIPLIER_ST   = (t_input:in)
->
                                        [7]t_scratch:
                                  #x3,x5,x11,x19,x2,x8,x30#
BEGIN
     MAC INPUT_TO_S(INT n) = (t_input: in)
->
                                   (flag,STRING[n]bit): BIOP TRANSFORM_S.
#the multiplier outputs, fast adder code commented out#
   LET   in_s= (INPUT_TO_S{input_exp}in)[2],
       x2=in_s CONC b"0",
       x8=in_s CONC b"000",
       x3 = ADD_S_ACTEL(in_s, x2,b'1),
       x5 = ADD_S_ACTEL(in_s,in_s CONC b"00",b'1 ),
       x11 = ADD_S_ACTEL(x3,x8,b'1),
       x19 = ADD_S_ACTEL(x3,in_s CONC b"0000",b'1),
```

```
        x30=ADD_S_ACTEL(x11,x19,b'1).

LET subsignal = (x2,x8, x3,x5 ,x11,x19,x30).
OUTPUT ((S_TO_I{input_exp+2} x3)[2],(S_TO_I{input_exp+3} x5)[2],(S_TO_I{input_exp+4} x11)[2],
        (S_TO_I{input_exp+5} x19)[2],(S_TO_I{input_exp+1} x2)[2],(S_TO_I{input_exp+3} x8)[2],
        (S_TO_I{input_exp+6} x30)[2])
END.
MAC INBUF{TYPE t} = (t:pad)
->
t:#y#pad.

MAC OBHS{TYPE t} = (t:d)
->
t:#pad#d.

FN CLKBUF = (bool:pad)
->
bool:pad.
#MAC SHIFT{INT p} = (STRING[scratch_exp]bit) ->STRING[scratch_exp+p]bit:BIOP SR_S{p}.#

MAC ADD_S = (STRING[INT m]bit,STRING[INT n]bit)
->
STRING[IF m>=n THEN m+1 ELSE n+1 FI]bit:
BIOP PLUS_S.

MAC INV{INT m} =(STRING[m]bit:a)
->
STRING[m]bit:BIOP NOT.

MAC NEG_S = (STRING[INT n]bit)
->
```

```
STRING[n+1]bit:
BIOP NEGATE_S.

MAC ADD_US = (STRING[INT m]bit,STRING[INT n]bit)
->
STRING[IF m>=n THEN m+1 ELSE n+1 FI]bit:
BIOP PLUS_US.

MAC CARRY= (t_add:in)
->
STRING[1]bit: CASE in
                                        OF add:b"0",
                                          sub:b"1"
                                  ESAC.
#actel adder macros#


#an emulation of a fast ACTEL 16 bit adder with active low carrys#
FN FADD16 = (STRING[scratch_exp]bit: a b,STRING[1]bit:cinb)
        ->
        (STRING[scratch_exp]bit,STRING[1]bit):
BEGIN
LET      a_c =a CONC INV{1}cinb ,
          b_c = b CONC INV{1} cinb ,
         out = ADD_S(a_c,b_c).
OUTPUT(out[2..scratch_exp+1],INV{1} B_TO_S out[1])
END.

#actel 1 bit full adder with active low cin and cout#
MAC FA1B = (bit: ain bin cinb)
        ->
```

```
(bit,bit):#cob,s#
BEGIN
LET    a_c =B_TO_S ain CONC INV{1}B_TO_S cinb ,
        b_c = B_TO_S bin CONC INV{1}B_TO_S cinb ,
      out = ADD_US(a_c,b_c).
OUTPUT(CAST{bit} INV{1} B_TO_S out[1], out[2])
END.


#the actel version of the ADD BIOP's#

MAC ADD_US_ACTEL = (STRING[INT m]bit:ain,STRING[INT n]bit:bin,bit:cinb)
                        ->
                                        STRING[IF m>=n THEN m+1 ELSE n+1 FI]bit:
BEGIN
        MAKE [IF m>=n THEN m ELSE n FI]FA1B:sum.

#unsigned nos so extend by 0#
        LET a_c = IF m>=n THEN ain ELSE ZERO{n-m}b"0" CONC ain FI,
       b_c = IF n>=m THEN bin ELSE  ZERO{m-n}b"0" CONC bin FI.
        LET subsignal = sum.

#lsb#
JOIN    (a_c[IF m>=n THEN m ELSE n FI],b_c[IF m>=n THEN m ELSE n FI],cinb)    ->sum[IF m>=n THEN m ELSE n FI].

FOR INT j=1..(IF m>=n THEN m ELSE n FI) -1
JOIN (a_c[(IF m>=n THEN m ELSE n FI) -j],b_c[(IF m>=n THEN m ELSE n FI) -j], sum[(IF m>=n THEN m ELSE n FI) -j+1][1])
>sum[(IF m>=n THEN m ELSE n FI) -j].

OUTPUT          CAST{STRING[IF m>=n THEN m+1 ELSE n+1 FI]bit}
(INV{1} B_TO_S sum[1][1] CONC
```

```
                CAST{STRING[IF m>=n THEN m ELSE n FI]bit} [INT j=1..IF m>=n THEN m ELSE n FI] sum[j][2])
END.


MAC ADD_S_ACTEL = (STRING[INT m]bit:ain,STRING[INT n]bit:bin,bit:cinb)
                        ->
                                        STRING[IF m>=n THEN m+1 ELSE n+1 FI]bit:
BEGIN
   MAKE [IF m>=n THEN m ELSE n FI]FA1B:sum.

#signed nos so sign extend #
 LET a_c = IF m>=n THEN ain ELSE ALL_SAME{n-m}B_TO_S ain[1]  CONC ain FI,
     b_c = IF n>=m THEN bin ELSE ALL_SAME{m-n}B_TO_S bin[1] CONC bin  FI.
      LET subsignal = sum.
#lsb#
JOIN   (a_c[IF m>=n THEN m ELSE n FI],b_c[IF m>=n THEN m ELSE n FI],cinb)    ->sum[IF m>=n THEN m ELSE n FI].

FOR INT j=1..(IF m>=n THEN m ELSE n FI) -1
JOIN (a_c[(IF m>=n THEN m ELSE n FI) -j],b_c[(IF m>=n THEN m ELSE n FI) -j], sum[(IF m>=n THEN m ELSE n FI) -j+1][1])        ->sum[(IF
m>=n THEN m ELSE n FI) -j]].

OUTPUT   CAST{STRING[IF m>=n THEN m+1 ELSE n+1 FI]bit}
(INV{1} B_TO_S sum[1][1] CONC
        CAST{STRING[IF m>=n THEN m ELSE n FI]bit} [INT j=1..IF m>=n THEN m ELSE n FI] sum[j][2])
END.

FN ROUND_BITS = (t_scratch:in,t_round: select)
                                  ->
                                        t_input:
BEGIN
```

```
#THIS ASSUMES THAT THE INPUT_EXP=10IIII#
        #select chooses a round factor of 3, 4,5#
        #the lsb is the right hand of the string,#
        #the index 1 of the string is the left hand end, &is the msb#
        #so on add ops bit 1 is the carryout#
        LET s1= (I_TO_S{scratch_exp}in)[2].

          msb= B_TO_S s1[1].

          selector =   CASE select          #case conversion for MUX_3#
              OF     shift3:l,
                    shift4:c,
                    shift5:r
              ESAC,

#needs to be a 16 bit output for the adder#
          shift = MUX_3{STRING[scratch_exp]bit}(
                          msb CONC msb CONC msb CONC s1[1..scratch_exp-3],
                          msb CONC msb CONC msb CONC msb CONC s1[1..(scratch_exp-4)],
                          msb CONC msb CONC msb CONC msb CONC msb CONC s1[1..scratch_exp-5],
                          selector
                                        ),

#the carry to round, 1/2 value is rounded towards 0#
          cs = CASE select
                          OF shift4: CASE msb
                                    OF b"1":s1[scratch_exp-3],       #neg no.#
                                     b"0": CASE s1[scratch_exp-3..scratch_exp]
                                         OF  b"1000": b'0        #round down on 1/2 value#
                                         ELSE  s1[scratch_exp-3]
                                         ESAC
```

```
                        ESAC,
        shift3: CASE msb
                        OF b"1":s1[scratch_exp-2],        #neg no.#
                          b"0": CASE s1[scratch_exp-2..scratch_exp]
                                OF  b"100": b'0          #round down on 1/2 value#
                                ELSE  s1[scratch_exp-2]
                                ESAC
                    ESAC,

        shift5: CASE msb
                        OF b"1":s1[scratch_exp-4],        #neg no.#
                          b"0": CASE s1[scratch_exp-4..scratch_exp]
                                OF  b"10000": b'0        #round down on 1/2 value#
                                ELSE  s1[scratch_exp-4]
                                ESAC
                        ESAC
    ESAC,

  sum17 =ADD_US_ACTEL(B_TO_S cs, shift,b'1),
  sum = sum17[2..scratch_exp+1],
                    #bit 1 is carry out, gives 16 bit sum#
  subsignal=(cs,sum),
#ACTEL HACK#
  soa = CASE sum[1]
   OF b'1: t,  #saturate to -512#
     b'0: f   #saturate to 512#
   ESAC,

 ss1 = CASE selector
    OF   I:      CASE  sum[4..7]  #these are the 5 msb's form the 13 bit word#
                 OF (b"1111" | b"0000"): t#value in range#
```

```
                ELSE f
                ESAC,

         c:     CASE  sum[5..7]#these are the 3 msb's from the 12 bit word left after#
                           # taking out the 4 sign extension bits#
                OF (b"111" | b"000"): t       #value in range#
                ELSE f
                ESAC,

         r:     CASE  sum[6..7] #these are the 2 msb's from the 11 bit word#
                OF (b"11" | b"00"): t #value in range#
                ELSE f
                               ESAC
             ESAC,
out= MXT{STRING[scratch_exp-6]bit}(b"0111111111",b"1000000000",sum[7..scratch_exp],sum[7..scratch_exp],soa,t,ss1).
      OUTPUT (S_TO_IN out)[2]
END.

MAC LINE_DELAY_ST{TYPE t}=([4]t:in,t_col:wr_address,t_col:rd_address,t_load:rw)
            ->
                  [4]t:
RAM([4]?t).

FN  PR_ADDER_ST = (t_scratch:a b )
->
      t_scratch:
(S_TO_I{scratch_exp} ADD_S((I_TO_S{scratch_exp-1}a)[2],(I_TO_S{scratch_exp-1}b)[2]) ) [2].


FN ADD_SUB_ST = (t_scratch: a b, t_add:sel)
->
```

```
I_scratch:
BEGIN

        LET a_s=(I_TO_S{scratch_exp}a)[2],
          b_s=(I_TO_S{scratch_exp}b)[2],
          sel_bit = CAST{STRING[1]bit}sel.
#ACTEL#
        b_s_inv = XOR_B{scratch_exp}(b_s, ALL_SAME{scratch_exp}sel_bit).

#cinb is active low so cast sel(add->0,sub->1) & invert it#
         out=    ADD_S_ACTEL(a_s ,b_s_inv,CAST{bit}INV{1}sel_bit ),
        binout= out[2..scratch_exp+1].
OUTPUT (S_TO_I{scratch_exp}binout)[2]
END.


MAC ALL_SAME{INT n} = (STRING[1]bit:dummy)
->
STRING[n]bit:
BEGIN
FAULT IF n < 1 THEN "N<1 in ALL_SAME" FI.
OUTPUT IF n=1 THEN dummy
ELSE dummy CONC ALL_SAME{n-1} dummy
FI
END.

MAC CAST {TYPE to} = (TYPE from:in)
->
        to:ALIEN CAST.
```

```
MAC ZERO(INT n) = (STRING[1]bit:dummy)
        ->
STRING[n]bit:
BEGIN
FAULT IF n < 1 THEN "N<1 in ZERO" FI.
OUTPUT IF n=1 THEN b"0"
    ELSE b"0" CONC ZERO(n-1) b"0"
    FI
END.

MAC B_TO_S= (bit:in)
        ->
                STRING[1]bit: CASE in
                        OF b'0:b"0",
                         b'1:b"1"
                  ESAC.

MAC I_TO_S(INT n) = (t_scratch: in)
        ->
                        (flag,STRING[n]bit): BIOP TRANSFORM_S.
MAC S_TO_I(INT n) = (STRING[n]bit:in)
->
 (flag,t_scratch): BIOP TRANSFORM_S.
MAC S_TO_IN = (STRING[input_exp]bit:in)
->
 (flag,t_input): BIOP TRANSFORM_S.
MAC IN_TO_S(INT n) = (t_input: in)
->
 (flag,STRING[n]bit): BIOP TRANSFORM_S.
MAC U_TO_I(INT n) = (STRING[n]bit:in)
->
```

```
(flag,t_scratch): BIOP TRANSFORM_U.

MAC B_TO_I= (bit:in)
->
t_scratch: CASE in
                              OF b'0:scratch/0,
                                 b'1:scratch/1
                         ESAC.

MAC CARRY= (t_add:in)
->
STRING[1]bit: CASE in
                              OF add:b"0",
                                 sub:b"1"
                         ESAC.


MAC BOOL_BIT = (bool:in)
->
STRING[1] bit:
CASE in
OF  t:b"1"
ELSE b"0"
ESAC.
MAC BIT_BOOL= (bit:in)
->
bool:
CASE in
OF  b'1:t
ELSE f
ESAC.
```

```
MAC BOOL_STRING{INT n} = ([n]bool:in)
->
STRING[n] bit:
(LET out = BOOL_BIT in[1].
OUTPUT IF n=1
        THEN out
        ELSE out[1] CONC  BOOL_STRING{n-1}(in[2..n])
        FI
).

#define a few useful gates #
FN NOT = (bool:in) ->bool:
        CASE in
        OF      t:f,
                f:t
        ESAC.
FN MUX = (bool:sel in1 in2) -> bool:
# two input mux, select in1 if sel =t ,otherwise in2 #
        CASE sel
        OF      t:in2,
                f:in1
        ESAC.
FN XNOR=(bool:in1 in2)->bool:
        CASE  (in1,in2)
        OF      (f,f):t,
                (f,t):f,
                (t,f):f,
                (t,t):t
        ESAC.
```

```
FN XOR=(bool:in1 in2)   ->bool:
        CASE    (in1,in2)
        OF      (f,f):f,
                (f,t):t,
                (t,f):t,
                (t,t):f
        ESAC.
FN OR = (bool:in1 in2)   ->bool:
        CASE    (in1,in2)
        OF      (t,bool)|(bool,t):t,
                (f,f)   : f
        ESAC.
#FN     MYLATCH = (bool:in)     ->bool:DELAY(f,1).#

FN      MYLATCH = (t_reset:reset,bool:in)          ->bool:
BEGIN
MAKE PDEL{bool,0}:del.
LET out = CASE reset
     OF rst:f
     ELSE   del
     ESAC.
JOIN in->del.
OUTPUT out
END.

TYPE t_test = NEW(no|yes).
#.............................................................#
#These functions change types from boolean to inputeger and vice- #
#versa. Supports 1 & 8 bit booleans.                       #
#.............................................................#
```

```
FN INT_BOOL=(t_input:k)        ->bool:            # 1bit input to binary #
              CASE   k
              OF     input/0:f,
                     input/1:t
       ESAC.

FN BOOL_INT=(bool:b) ->t_input:                   # 1 bit bool to input #
              CASE   b
              OF     f:input/0,
                     t:input/1
       ESAC.

FN * =(t_input:a b)      ->t_input: ARITH a*b.
FN % =(t_input:a b)      ->t_input: ARITH a%b.
FN - =(t_input:a b)      ->t_input: ARITH a-b.
FN + =(t_input:a b)      ->t_input: ARITH a+b.
FN = =(t_input:a b)      ->t_test: ARITH IF a=b THEN 2 ELSE 1 FI.

COM
FN CHANGE_SIGN = (t_input:i) ->t_input:       #changes sign for 8-bit 2's#
       ARITH  IF i<0 THEN 128+i         #complement no,  #
                  ELSE i
                  FI.

FN SIGN = (t_input:i)     ->bool:           #gets sign for 2's#
       ARITH  IF i<0 THEN 1          #complement nos  #
                  ELSE 2
                  FI.

FN TEST_SIZE = (t_input:x)      ->bool:
```

```
#tests to see if the input is bigger than an 8-bit inputeger#
        ARITH IF ( (x<=-128) AND (x>127)) THEN 1
                                          ELSE 2        FI.


FN INT8_BOOL=(t_input:orig)    ->[8]bool:
BEGIN

        SEQ
                VAR i1:=input/0,          #input variables#
                  i0:=CHANGE_SIGN(orig),
                  b:=(f,f,f,f,f,f,f,SIGN(orig));
        [INT n=1..7]      (
                        i1:=i0%input/2;
                        b[n]:=INT_BOOL(i0-input/2*i1);
                        i0:=i1
                        );
        OUTPUT          CASE TEST_SIZE orig          #checks to see if orig will#
                OF      t:      [8]?bool,        #fit inputo an 8_bit value#
                        f:      b
                ESAC
END.

FN BOOL_INT8=([8]bool:b)       ->t_input:        #converts 8bit boolean to 2's#
BEGIN
        SEQ                               #complement inputeger #
                VAR     sum:=input/-128 * BOOL_INT(b[8]),
                        exp:=input/1;
                [INT k=1..7]
                        (       sum:=sum+exp*BOOL_INT(b[k]);
                                exp:=input/2 * exp
```

```
                    );
          OUTPUT  sum
END.


MOC
FN BOOL_INT10=([10]bool:b)    ->t_input:          #converts 10bit boolean to 2's#
BEGIN
          SEQ                                   #complement integer     #
                    VAR     sum:=input/-512 * BOOL_INT(b[10]),
                            exp:=input/1;
                    [INT k=1..9]
                            (         sum:=sum+exp*BOOL_INT(b[k]);
                                      exp:=input/2 * exp
                            );
          OUTPUT  sum
END.
COM
FN BOOL_INT16 =([8]bool:in1 in2)          ->t_input:
# convetrs a 16-bit no., (lsbs,msbs) inputo inputeger form)#
(BOOL_INT8(in1))+((input/256)*BOOL_INT8(in2))+((input/256)*BOOL_INT(in1[8])).
                                                          #hack because of sign extend#
                                                                    #of lsb #
MOC
#compute the mean square difference between two arrays of integers#

FN MSE_COLOUR = (t_reset:reset,t_input:a b)    ->[2]t_int32:
BEGIN
          FN SAVE_ERROR = (t_reset:reset,t_int32:diff32) ->t_int32:
          BEGIN
                    MAKE PDEL{t_int32,0}:del,
```

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```
             PDEL{t_reset,0}:edge.

LET     rising = CASE (reset,edge)
                  OF      (no_rst,rst):diff32,
                          (no_rst,no_rst):del PL diff32
                 ELSE   del
                 ESAC.
JOIN    rising    ->del,
        reset     ->edge.
OUTPUT           del
END.

MAKE   SAVE_ERROR:save_error.
LET out =(SEQ
        STATE VAR true_count INIT int32/1;
        VAR diff:=int32/0,
        diff32:=int32/0,
        incr:=int32/0;

diff:=CASE reset
        OF rst:int32/0
        ELSE I_32(a) MI I_32(b)
        ESAC;
incr:=CASE reset
        OF rst:int32/0
        ELSE int32/1
        ESAC;
true_count:= CASE reset
           OF rst:int32/1
           ELSE true_count PL incr
                ESAC;
```

```
        diff32:= (diff TI diff);

    OUTPUT (diff32,true_count) ).

    JOIN        (reset,out[1])          ->save_error.
    OUTPUT      (save_error,save_error DV out[2])
    END.


#compute the mean square difference between two arrays of integers#

TYPE t_int32 = NEW int32/(-2147483000..2147483000).
INT period_row=9.

FN I_32 = (t_input:in)      ->t_int32:ARITH in.

FN DV = (t_int32:a b)       ->t_int32:ARITH a%b.
FN PL = (t_int32:a b)       ->t_int32:ARITH a+b.
FN MI = (t_int32:a b)       ->t_int32:ARITH a-b.
FN TI = (t_int32:a b)       ->t_int32:ARITH a*b.


FN MSE_ROW = (t_input:a b)    ->[3]t_int32:
BEGIN SEQ
            STATE VAR err INIT int32/0,
                  count INIT int32/0;
            VAR diff:=int32/0,
            diff32:=int32/0;

    count:=count PL int32/1;
```

```
        diff:=CASE count
                OF int32/(1..period_row):int32/0
                ELSE I_32(a) MI I_32(b)
                ESAC;
        diff32:= (diff TI diff);
        err:=err PL diff32;
OUTPUT (err, err DV count,count)
END.


FN PRBS10 = (t_reset:reset)      ->[10]bool:
#A 10 bit prbs generator,feedback taps on regs 3 & 10.#
BEGIN
        MAKE  [10]MYLATCH:l,
              XNOR:xnor.

        FOR INT k=1..9 JOIN
              (reset,l[k])        ->l[k+1].

        JOIN  (reset,xnor)        ->l[1],
              (l[10],l[3])        ->xnor.

        OUTPUT        l
END.
FN PRBS11 = (t_reset:reset)      ->[10]bool:
#A 11 bit prbs generator,feedback taps on regs 2 & 11.#
BEGIN
        MAKE  [11]MYLATCH:l,
              XNOR:xnor.
```

```
        FOR INT k=1..10         JOIN
                (reset,l[k])    ->l[k+1].

        JOIN    (reset,xnor)    ->l[1],
                (l[11],l[2])    ->xnor.

        OUTPUT          l[1..10]
END.
COM
FN PRBS16 = (bool:reset)        ->[16]bool:
#A 16 bit prbs generator,feedback taps on regs 1,3,12,16#
BEGIN
        MAKE    [16]MYLATCH:l,
                XOR_4:xor,
                NOT:xnor.

        FOR INT k=1..15         JOIN
                (ck,reset,l[k]) ->l[k+1].

        JOIN    (ck,reset,xnor) ->l[1],
                (l[1],l[3],l[16],l[12])         ->xor,
                xor             ->xnor.
        OUTPUT          ([INT k=1..16]l[k])
END.
FN PRBS12 = (clock:ck,bool:reset)       ->[12]bool:
#A 12 bit prbs generator,feedback taps on regs 1,4,6,12.#
BEGIN
        MAKE    [12]MYLATCH:l,
                XOR_4:xor,
                NOT:xnor.
```

```
        FOR INT k=1..11          JOIN
                (ck,reset,l[k])    ->l[k+1].

        JOIN    (ck,reset,xnor)  ->l[1],
                (l[1],l[4],l[6],l[12])        ->xor,
                xor                ->xnor.
        OUTPUT          ([INT k=1..12]l[k])
END.

FN PRBS8 = (clock:ck,bool:reset)          ->[8]bool:
#A 8 bit prbs generator,feedback taps on regs 2,3,4,8.#
BEGIN
        MAKE   [8]MYLATCH:l,
                XOR_4:xor,
                NOT:xnor.

        FOR INT k=1..7 JOIN
                (ck,reset,l[k])     ->l[k+1].

        JOIN    (ck,reset,xnor)  ->l[1],
                (l[2],l[3],l[4],l[8]) ->xor,
                xor                 ->xnor.
        OUTPUT          ([INT k=1..8]l[k])
        END.
MOC
#TEST FOR Y U V #
#to test the 2d convolver using prbs input into the forward convolver#
#then outputting to the inverse convolver and checking against the original result#
```

```
FN TEST_COLOUR = (bool:ck,t_reset:reset,bool:extwritel_in csl_in, t_sparc_addr:reg_sel value,t_reset:prbs_reset)
                    ->[3]t_int32:

BEGIN
    FN DEL = (t_load:in)      ->t_load:DELAY(read,1).

    FN PULSE = (t_load:in) ->t_reset:
    CASE (in,DEL in)
    OF      (write,read):rst
    ELSE    no_rst
    ESAC.

    MAKE PRBS11:prbs,
    BOOL_INT10:int_bool,
    DWT:dwt,
    [3]MSE_COLOUR:mse_colour.

JOIN    (CASE (prbs_reset,PULSE CASE dwt[3][2]
                            OF write:read,
                              read:write
                            ESAC,PULSE CASE dwt[3][3]
              OF write:read,
                read:write
                            ESAC,PULSE dwt[2][1],PULSE dwt[2][2],PULSE dwt[2][3])

                                        #rerun the prbs at start, or on out of IDWT#
OF      (rst,t_reset,t_reset,t_reset,t_reset,t_reset)|(t_reset,rst,t_reset,t_reset,t_reset,t_reset)|
        (t_reset,t_reset,rst,t_reset,t_reset,t_reset)|(t_reset,t_reset,t_reset,rst,t_reset,t_reset)|
        (t_reset,t_reset,t_reset,t_reset,rst,t_reset)|(t_reset,t_reset,t_reset,t_reset,t_reset,rst):rst
        ELSE    no_rst
        ESAC)                       ->prbs,
```

```
        prbs             ->int_bool,
        (ck,reset,int_bool,extwritel_in,csl_in, reg_sel,value)        ->dwt.

#calcuate the mse error for each channel#
        FOR INT j=1..3 JOIN
        (CASE dwt[2][j]
         OF read:rst
         ELSE no_rst
         ESAC,dwt[1],int_bool)   ->mse_colour[j].
OUTPUT (mse_colour[1][1],mse_colour[2][1],mse_colour[3][1])
END.
FN DWT = (bool,t_reset,t_input,bool,bool,t_sparc_addr:reg_sel value)     ->(t_input,[3]t_load,[3]t_load):IMPORT.
MAC PDEL{TYPE t, INT n} =(t)   ->t:IMPORT.

IMPORTS              dwt/string: DWT_TEST( RENAMED DWT) PDEL.


#TEST FOR LUMINANCE ONLY#
#to test the 2d convolver using prbs input into the forward convolver#
#then outputting to the inverse convolver and checking against the original result#


FN TEST_Y = (bool:ck,t_reset:reset,bool:extwritel_in csl_in, t_sparc_addr:reg_sel value,t_reset:prbs_reset)
                     ->[2]t_int32:

BEGIN
        FN DEL = (t_load:in)     ->t_load:DELAY(read,1).

        FN PULSE = (t_load:in) ->t_reset:
        CASE (in,DEL in)
```

```
        OF      (write,read):rst
        ELSE    no_rst
        ESAC.

        MAKE PRBS11:prbs,
        BOOL_INT10:int_bool,
        DWT:dwt,
        MSE_COLOUR:mse_colour.

JOIN    (CASE (prbs_reset,PULSE dwt[2][1])      #rerun the prbs at start, or on out of IDWT#
        OF      (rst,t_reset)|(t_reset,rst):rst
        ELSE    no_rst
        ESAC)                           ->prbs,

        prbs            ->int_bool,
        (ck,reset,int_bool,extwritel_in,csl_in, reg_sel,value)          ->dwt,
        (CASE dwt[2][1]
         OF  read:rst
         ELSE no_rst
         ESAC,dwt[1],int_bool)   ->mse_colour.
OUTPUT mse_colour
END.
```

APPENDIX B-2

```
#test for abs #

FN ABS_TEST = (STRING[10]bit:in in2)     ->bool: in LE_U in2.
#the state machine to control the address counters#
#only works for 3 octave decomposition in y/2 in u|v#


FN CONTROL_ENABLE = (bool:ck,t_reset:reset,t_channel:new_channel channel,[3]bool:c_blk,STRING[2]bit:subband,
            t_load:load_channel, t_mode:new_mode)

            ->([3]bool#en_blk#,t_octave,[2]bool#tree_done,lpf_block_done#,t_state#reset_state#):
BEGIN
        MAKE DF1{t_state}:state.
#set up initial state thro mux on reset, on HH stay in zz0 state#
LET    start_state = CASE channel
            OFu|v:down1,
                y:up0
            ESAC,
    reset_state= CASE reset
            OF   rst: start_state
            ELSE state
            ESAC.

LET next_values = (SEQ
        VAR en_blk:=[3]f,    #enable blk_count#
            lpf_block_done:=f,        #enable x_count for LPF#
            tree_done:=f,      #enable x_count for other subbands#
            new_state:=reset_state,
            octave:=?t_octave;   #current octave#

     CASE  reset_state
```

```
        ELSE
        ESAC),
    zz1: ( octave:=oct/0;
         en_blk[1]:=t;
         CASE c_blk[1]
         OF     t:(new_state:=zz2;
                en_blk[2]:=t)
         ELSE
         ESAC),
    zz2: ( octave:=oct/0;
         en_blk[1]:=t;
         CASE c_blk[1]
         OF     t:(new_state:=zz3;
                en_blk[2]:=t)
         ELSE
         ESAC),
    zz3: ( octave:=oct/0;
         en_blk[1]:=t;
#now decide the next state, on block(1) carry check the other block carries#
         CASE c_blk[1]
         OF     t:(new_state:=down1;
         en_blk[2]:=t;   #roll over to 0#
         en_blk[3]:=t        #because state zz3 clock 1 pulse#
                )
         ELSE
         ESAC

      ),
      down1: ( octave:=oct/1;
           en_blk[2]:=t;
           CASE c_blk[2]
```

```
OFup0: ( octave:=oct/2;
        en_blk[3]:=t;
            CASE c_blk[3]
            OF      t:(CASE subband
                        OF b"00":lpf_block_done:=t      #clock x_count for LPF y channel#
                        ELSE  new_state:=up1    #change state when count done#
                       ESAC;

             CASE new_mode     #in luminance & done with that tree#
             OF  stop:tree_done:=t
             ELSE
             ESAC)
            ELSE
            ESAC),
        up1: ( octave:=oct/1;
        en_blk[2]:=t;
             CASE c_blk[2]
             OF      t:(new_state:=zz0;

           CASE new_mode   #in luminance, terminate branch & move to next branch#
           OFstop:(new_state:=down1;
                  en_blk[3]:=t)
           ELSE
           ESAC)
        ELSE
             ESAC),
        zz0: ( octave:=oct/0;
         en_blk[1]:=t;
             CASE c_blk[1]
             OF      t:(new_state:=zz1;
              en_blk[2]:=t)
```

```
    OF     t:(CASE subband
            OF b"00":lpf_block_done:=t       #clock x_count for LPF u|v channel#
            ELSE  new_state:=zz0    #change state when count done#
    ESAC;

    CASE (new_mode,channel)        #stop so finish this tree/branch & move on#
    OF    (stop,u|v):tree_done:=t,
       (stop,y):(en_blk[3]:=t;
           CASE c_blk[3]       #move to next tree#
           OFt:tree_done:=t
           ELSE    new_state:=down1
           ESAC
           )
    ELSE
    ESAC)
      ELSE
      ESAC)

ESAC;

CASE channel
OF u|v:  CASE (c_blk[1],c_blk[2])
            OF      (t,t):tree_done:=t
            ELSE
            ESAC,
     y:  CASE (c_blk[1],c_blk[2],c_blk[3])
            OF      (t,t,t):tree_done:=t
            ELSE
            ESAC
ESAC;
```

```
#now change to start state if the sequence has finished#
   CASE      tree_done     #in LPF state doesnt change when block done#
   OFt: new_state:= start_state
   ELSE
   ESAC;
#on channel change, use starting state for new channel#
     CASE   load_channel       #in LPF state doesnt change when block done#
     OF      write: new_state:= CASE new_channel
                 OFy:up0,
                     u|v:down1
                 ESAC
   ELSE
   ESAC;


OUTPUT (new_state,en_blk,octave,(tree_done,lpf_block_done))
).


JOIN  (ck,next_values[1]) ->state.
OUTPUT (next_values[2],next_values[3],next_values[4],reset_state)
END.

FN CHECK = (t_input:x sub size y,t_octave: oct) ->t_sparc_addr:
      ARITH (( x SL 1)+(1 IAND sub) + size*((y SL 1) +(sub SR 1)))SL oct.


#these are the addr gens for the x & y adresses of a pixel given the octave#
#sub&blk no. for each octave.Each x&y address is of the form       #
#   x= count(5 bits){blk(3)..blk(octave+1)}{s} {octave 0's}         #
```

```
#  y= count(5 bits){blk(3)..blk(octave+1)}{s} {octave 0's}        #
#this makes up the 9 bit address for CIF images             #
#the blk & s counters are vertical 2 bit  with the lsb in the x coord  #
#and carry out on 3, last counter is both horiz and vertical counter#
#read_enable enable the block count for the read address, but not the    #
#carry-outs for the mode change, this is done on the write addr cycle #
#by write_enable, so same address values generated on read & write cycles#

FN ADDR_GEN = (bool:ck, t_reset:reset,t_channel:new_channel channel,t_load:load_channel,STRING[2]bit:sub_count,
        STRING[xsize]bit:col_length,STRING[ysize]bit:row_length,STRING[xsize]bit:ximage_string,
        STRING[ysize]bit:yimage_string ,STRING[11]bit:yimage_string_3#yimage*2.5#,
        bool:read_enable write_enable, t_mode:new_mode)

        -> (t_sparc_addr,t_octave,bool#sub finished#,bool#tree_done#,bool#lpf_done#,t_state):
BEGIN
    MAKECOUNTER{xsize-4}:x_count,
        COUNTER{ysize-4}:y_count,
        CONTROL_ENABLE:control,
        [3]BLK_SUB_COUNT:blk_count.

#size of lpf images/2 -1, for y,u|v.  /2 because count in pairs of lpf values #
#lpf same size for all channels!!!#

LET    (x_lpf,y_lpf) = (col_length[1..xsize-4], row_length[1..ysize-4]),

     tree_done = control[3][1],
     lpf_block_done = control[3][2],
     x_en = CASE (tree_done,lpf_block_done)
         OF(t,bool)|(bool,t):t
         ELSE f
         ESAC,
```

```
  blk_en=control[1],
  octave=control[2],

#clk y_count when all blocks done for subs 1-3, or when final blk done for lpf#

   y_en =      CASE sub_count
       OFb"00":CASE (lpf_block_done, x_count[2])
             OF (t,t):t
             ELSE f
             ESAC
       ELSE CASE (tree_done, x_count[2])
          OF (t,t):t
          ELSE f
          ESAC
       ESAC,

   x_msb_out =CASE channel
       OF  y: x_count[1] CONC B_TO_S(blk_count[3][1][2]),      #always the msb bits#
        u|v: b"0" CONC x_count[1]
       ESAC,
   y_msb_out = CASE channel
       OF  y:y_count[1] CONC B_TO_S(blk_count[3][1][1]),
        u|v:b"0" CONC y_count[1]
       ESAC,

  x_lsb_out =CASE (octave)        #bit2 is lsb#
    OF (oct/0):([INT k=1..2]blk_count[3-k][1][2])CONC sub_count[2],
       (oct/1):(blk_count[2][1][2], sub_count[2] , b'0),
        (oct/2):sub_count[2] CONC [2]b'0
       ESAC,
```

```
y_lsb_out =CASE (octave)        #bit 1 is msb#
     OF    (oct/0):([INT k=1..2]blk_count[3-k][1][1])CONC sub_count[1],
          (oct/1):(blk_count[2][1][1] , sub_count[1] , b'0),
          (oct/2):sub_count[1] CONC [2]b'0
          ESAC,
   x_addr = x_msb_out CONC BIT_STRING{3}x_lsb_out,
   y_addr = y_msb_out CONC BIT_STRING{3}y_lsb_out,

#enable the sub band counter#
     sub_en = CASE (y_count[2],y_en)
          OF     (t,t):t
         ELSE   f
       ESAC,

     lpf_done = CASE sub_count
           OF  b"00": sub_en            #!!!!CHANGE ACCORDING TO LATENCY IN DECODE#
           ELSE f
           ESAC,

    base_y_sel = CASE channel
          OF   y:l,
           u:c,
           v:r
          ESAC,

    base_rows = MUX_3{STRING[11]bit}(ZERO{11}b"0",b"0" CONC yimage_string[1..ysize]CONC b"0",
                              yimage_string_3,base_y_sel),
 #base address for no of rows for y,u &v memory areas#

    address = x_addr ADD_U ( ((y_addr ADD_U base_rows)[2..12]) MULT_U (CASE channel
                    OFy:ximage_string,
```

```
                  u|v:(SR_U{1}ximage_string)[1..xsize]
                ESAC)
            ),

   int_addr = (S_TO_SPARC address)[2].

JOIN    (ck,reset,x_en,x_lpf)          ->x_count,
      (ck,reset,y_en,y_lpf)          ->y_count,
#use new_channel so on channel change control state picks up correct value#
      (ck,reset,new_channel,channel,([INT j=1..3]blk_count[j][2]),sub_count,load_channel,new_mode)
                  ->control.
FOR INT k=1..3 JOIN  (ck,reset,blk_en[k],read_enable OR write_enable,write_enable)       ->blk_count[k].


OUTPUT (int_addr,octave, sub_en,tree_done, lpf_done,control[4])
END.

#a counter to control the sequencing of r/w, token, huffman cycles#
#decide reset is enabled 1 cycle early, and latched to avoid glitches#
#lpf_stop is a is a dummy mode to disable the block writes&huffman data#
#cycles for that block#

FN CONTROL_COUNTER = (bool:ck,t_reset:reset,t_mode:mode new_mode,t_direction:direction)
          ->(t_load,t_cycle,t_reset,bool,bool,t_load,t_cs,t_load,t_cs):

#mode load,cycle,decide reset,read_addr_enable,write_addr_enable,load flags#
#decode write_addr_enable early and latch to avoid feedback loop with pro_mode#
#in MODE_CONTROL#
BEGIN
   MAKE COUNT_SYNC{4}:count.
```

```
LET   count_len = (U_TO_LEN{4} count[1])[2].

LET   out = (SEQ
      VAR    cycle:=skip_cycle,
          decide_reset:= no_rst,
          load_mode:=read,
          load_flags:=read,
          cs_new:=no_select,
          cs_old:=select,
          rw_old:=read,
          read_addr_enable:=f,
          write_addr_enable:=f;

 CASE direction
 OFforward: CASE mode
       OF send|still_send|lpf_send:  CASE    count_len
                         OF   len/(0..3):(read_addr_enable:=t;
                                  cs_new:=select),
                           len/(4):(cycle:=token_cycle;
                               load_flags:=write;
                               write_addr_enable:=t),

                           len/(5..7) : (write_addr_enable:=t;
                               CASE new_mode
                               OFstop|lpf_stop:(cycle:=skip_cycle;
                                          rw_old:=read;
                                          cs_old:=no_select),
                                   void:(cycle:=skip_cycle;
                                       rw_old:=write)
                               ELSE (cycle:=data_cycle;
                                          rw_old:=write)
```

```
        ESAC),
      len/8:(decide_reset:=rst;
        CASE new_mode
                OF     stop|pf_stop:(cycle:=skip_cycle;
                                rw_old:=read;
                                cs_old:=no_select),
          void:(cycle:=skip_cycle;
                    load_mode:=write;
                        rw_old:=write)

                ELSE   (cycle:=data_cycle;
                load_mode:=write;
                   rw_old:=write)
                ESAC)
     ELSE
     ESAC,

still:     CASE   count_len
             OF    len/(0..3):(read_addr_enable:=t;
                         cs_new:=select),
                len/(4):(cycle:=token_cycle;
                   write_addr_enable:=t;
                   load_flags:=write),
                len/(5..7):( rw_old:=write;
                         write_addr_enable:=t;
                   CASE new_mode
                   OF     void_still:cycle:=skip_cycle
                   ELSE   cycle:=data_cycle
                   ESAC),

                len/8:(decide_reset:=rst;
```

```
                  rw_old:=write;
                  load_mode:=write;
                  CASE new_mode
                  OF     void_still:cycle:=skip_cycle
                  ELSE   cycle:=data_cycle
                  ESAC)

            ELSE
            ESAC,

lpf_still:  CASE   count_len
            OF     len/(0..3):(read_addr_enable:=t;
                         cs_new:=select),
               len/(4):(cycle:=token_cycle;
                    write_addr_enable:=t;
                    load_flags:=write),
               len/(5..7):(cycle:=data_cycle;
                         rw_old:=write;
                         write_addr_enable:=t),
               len/8:( cycle:=data_cycle;
                    rw_old:=write;
                    decide_reset:=rst;
                    load_mode:=write)
            ELSE
            ESAC,

void:       CASE count_len
                 OF   len/(0..3):(read_addr_enable:=t;
                 cs_new:=select),
            len/4:(load_flags:=write;
               cycle:=token_cycle;  #dummy token cycle for mode update#
```

```
write_addr_enable:=t),
        len/(5..7):(write_addr_enable:=t; #keep counters going#
  CASE new_mode
              OF     stop:(rw_old:=read;
                           cs_old:=no_select)
  ELSE rw_old:=write
  ESAC),
        len/8:( decide_reset:=rst;
 CASE new_mode
          OF     stop:(rw_old:=read;
                       cs_old:=no_select)
 ELSE    (load_mode:=write;
                 rw_old:=write)
 ESAC)

    ELSE
    ESAC,

void_still:   CASE  count_len
                 OF   len/0: write_addr_enable:=t,    #allow for delay#
              len/(1..3):(write_addr_enable:=t;
                    rw_old:=write),
                         len/4:(rw_old:=write;
                               load_mode:=write;
               decide_reset:=rst)
                   ELSE
                   ESAC
  ELSE
  ESAC,

inverse: CASE mode
```

```
OF send|still_send|lpf_send: CASE count_len
                 OF   len/(0..3):(read_addr_enable:=t),
                    len/(4):(cycle:=token_cycle;
                        write_addr_enable:=t;
                        load_flags:=write),
                    len/(5..7) : (write_addr_enable:=t;
                        CASE new_mode
                        OF     stop|lpf_stop:(cycle:=skip_cycle;
                                    rw_old:=read;
                                    cs_old:=no_select),
                            void:(cycle:=skip_cycle;
                                rw_old:=write)
                        ELSE   (cycle:=data_cycle;
                            rw_old:=write)
                        ESAC),
                    len/8:(decide_reset:=rst;
                        CASE new_mode
                        OF     stop|lpf_stop:(cycle:=skip_cycle;
                                    rw_old:=read;
                                    cs_old:=no_select),
                            void:(cycle:=skip_cycle;
                                load_mode:=write;
                                rw_old:=write)

                        ELSE   (cycle:=data_cycle;
                            load_mode:=write;
                            rw_old:=write)
                        ESAC)

                 ELSE
                 ESAC,
```

```
still:        CASE  count_len
                 OF  len/(0):,        #skip to allow reset in huffman#
          len/(1):(cycle:=token_cycle;
                          write_addr_enable:=t),
          len/(2..4):(rw_old:=write;
                          write_addr_enable:=t;
              CASE new_mode
              OFvoid_still:cycle:=skip_cycle
              ELSE cycle:=data_cycle
              ESAC),

                    len/5:( rw_old:=write;
                          decide_reset:=rst;
              load_mode:=write;
              CASE new_mode
                          OF     void_still:cycle:=skip_cycle
                          ELSE   cycle:=data_cycle
                          ESAC)
                 ELSE
                 ESAC,
tpf_still:    CASE  count_len
                 OF  len/(0):,        #match with previous#
          len/(1):(            #skip for write enb delay#
                          write_addr_enable:=t),
                    len/(2..4):(cycle:=data_cycle;
                          rw_old:=write;
                          write_addr_enable:=t),
                    len/5:(cycle:=data_cycle;
                          rw_old:=write;
                          decide_reset:=rst;
                          load_mode:=write)
```

```
                ELSE
                ESAC,
void:           CASE count_len
                OF   len/(0..3):(read_addr_enable:=t),
                     len/4:(load_flags:=write;
             cycle:=token_cycle;  #dummy token cycle for mode update#
                        write_addr_enable:=t),
                     len/(5..7):(write_addr_enable:=t;
                CASE new_mode
                         OF      stop:(rw_old:=read;
                                       cs_old:=no_select)
                         ELSE rw_old:=write
                         ESAC),
                     len/8:( decide_reset:=rst;
                         CASE new_mode
                         OF      stop:(rw_old:=read;
                                       cs_old:=no_select)
                         ELSE    (load_mode:=write;
                                  rw_old:=write)
                         ESAC)
                ELSE
                ESAC,
void_still:     CASE count_len
                OF  len/(0):,           #match with rest#
          len/1:write_addr_enable:=t, #dummy as write delayed#
                     len/(2..4):(write_addr_enable:=t;
                                 rw_old:=write),
                     len/5:  (rw_old:=write;
              load_mode:=write;
              decide_reset:=rst)
                ELSE
```

```
                        ESAC
          ELSE
          ESAC
ESAC;

   OUTPUT (load_mode,cycle,DF1{t_reset}(ck,decide_reset),read_addr_enable,
      DFF{bool}(ck,reset,write_addr_enable,f),load_flags,
      cs_new,rw_old,cs_old)
).

JOIN  (ck,CASE reset
       OF   rst:rst
       ELSE out[3]
       ESAC,t)      ->count.

OUTPUT out
END.

#...........................................................#
#A set of boolean ,ie gate level counters                   #
#...........................................................#

#...........................................................#
#The basic toggle flip-flop plus and gate for a synchronous counter   #
#input t is the toggle ,outputs are q and tc (toggle for next counter#
#stage                                        #
#...........................................................#

MAC  BASIC_COUNT = (bool:ck ,t_reset:reset,bool: tog)    ->(STRING[1]bit,bool):
```

```
BEGIN
    MAKE DFF{bool}:dlat,
        XOR   :xor,
        AND   :and.

    JOIN  (ck,reset,xor,f)->dlat,
        (dlat,tog)    ->and,
        (tog,dlat)    ->xor.
    OUTPUT (CAST{STRING[1]bit} dlat,and)
END.

#.................................................................#
# The n-bit macro counter generator, en is the enable, the outputs   #
#are msb(bit 1).....lsb,carry.This is the same order as ELLA strings are stored#
#.................................................................#

MAC COUNT_SYNC{INT n} = (bool:ck,t_reset: reset,bool: en )->(STRING[n]bit,bool):
(LET out = BASIC_COUNT(ck,reset,en) .

  OUTPUT        (   IF n=1
            THEN (out[1],out[2])
            ELSE ( LET outn = COUNT_SYNC{n-1}(ck,reset,out[2]) .
            OUTPUT (outn[1] CONC out[1],outn[2])
            )
            FI)
 ).
 COM
 FN TEST_COUNT_SYNC = (bool:ck,t_reset: reset,bool: en ) ->([4]bool,bool):
     COUNT_SYNC{4}(ck,reset,en).
 MOC
```

```
#..............................................................#
#The basic toggle flip-flop plus and gate for a synchronous counter   #
#input t is the toggle, updown detms the direction ,outputs are q and #
# tc (toggle for next counterstage, active low for down/high for up)  #
#..............................................................#

MAC  BASIC_COUNT_UD = (bool:ck ,t_reset:reset,bool: tog, t_updown:updown)   ->[2]bool:

BEGIN
           MAKE DFF{bool}:dlat.
    LET    toggle = tog,
     xorn = CASE updown
          OF  up: CASE (toggle,dlat) #xor#
              OF   (t,t)|(f,f):f
              ELSE t
              ESAC,
           down:CASE (toggle,dlat) #xnor#
                   OF   (t,t)|(f,f):t
                   ELSE f
                   ESAC
         ESAC,
     cout = CASE updown
        OFup:CASE (dlat,toggle)  #AND#
               OF (t,t):t
               ELSE  f
               ESAC,
            down:CASE (dlat,toggle)   #OR#
               OF(f,f):f
               ELSE   t
               ESAC
```

```
      ESAC.

        JOIN  (ck,reset,xom,f)->dlat.
        OUTPUT (dlat,cout)
END.

#..............................................................#
# The n-bit macro u/d counter generator, en is the enable, the outputs  #
#are msb(bit 1).....lsb,carry.This is the same order as ELLA strings are stored#
#first enable is active low on down, so invert.             #
#..............................................................#
MAC COUNT_SYNC_UD{INT n} = (bool:ck,t_reset: reset,bool:en, t_updown:updown)     ->(STRING[n]bit,bool):
BEGIN
   MAKE [n]BASIC_COUNT_UD:basic_count.
   LET enable = ([INT k=1..n-1] basic_count[k+1][2]) CONC CASE updown      #invert enable if down count#
                                      OF  up:en
                                     ELSE NOT en
                                     ESAC .
   FOR INT k=1..n JOIN  (ck,reset,enable[k],updown)   ->basic_count[k].
OUTPUT (BOOL_STRING{n}([INT k=1..n]basic_count[k][1]), basic_count[1][2])
END.

COM
FN TEST_COUNT_SYNC_UD = (bool:ck,t_reset: reset,bool: en,t_updown:updown ) ->([4]bool,bool):
          COUNT_SYNC_UD{4}(ck,reset,en,updown).
MOC


#the basic x/y counter, carry out 1 cycle before final count given by x_lpf/y_lpf#
MAC COUNTER{INT n} = (bool:ck,t_reset:reset,bool:en,STRING[n]bit:x_lpf)  ->(STRING[n]bit,bool):
BEGIN
```

```
MAKE    COUNT_SYNC{n}:x_count.

LET out =  x_count[1],
   final_count = out EQ_U x_lpf,
   final_count_en=CASE (final_count,en)
          OF  (t,t):t
          ELSE f
          ESAC,
#reset after 4 counts at final count value#
    cnt_reset = CASE reset
         OF   rst:rst
         ELSE CASE DF1{bool}(ck,final_count_en) #reset taken out of DFF 12/6#
              OFt:rst
              ELSE no_rst
              ESAC
         ESAC.
 JOIN  (ck,cnt_reset,en)    ->x_count.
 OUTPUT (out,final_count)
 END.
 COM
 #the basic y  counter, carry out 1 cycle before final count given by y_lpf#
 #reset at end of channel given by system reset                #
 MAC Y_COUNTER = (bool:ck,t_reset:reset,bool:en,STRING[4]bit:y_lpf)  ->(STRING[4]bit,bool):
 BEGIN

 MAKE   COUNT_SYNC{4}:y_count.

 LET out =  y_count[1].
 JOIN    (ck,reset,en)   ->y_count.
 OUTPUT (out, out EQ_U y_lpf)
```

```
END.
MOC


COM
#the blk, or sub-band counters, carry out on 3#
FN BLK_SUB_COUNT = (bool:ck,t_reset:reset, bool:en)        ->(STRING[2]bit,bool):
BEGIN
   MAKE COUNT_SYNC{2}:blk_count.
   LET out = blk_count[1].
   JOIN (ck,reset,en)  ->blk_count.
OUTPUT(out,out EQ_U (C_TO_S{2}col/3)[2])
END.
MOC

#the blk, or sub-band counters, carry out on 3, cout_en enables the carry out, & cin_en AND en  enables the count#
FN BLK_SUB_COUNT = (bool:ck,t_reset:reset, bool:en cin_en cout_en)          ->(STRING[2]bit,bool):
BEGIN
      MAKE COUNT_SYNC{2}:blk_count.
      LET out = blk_count[1].
      JOIN (ck,reset,en AND cin_en)      ->blk_count.
OUTPUT(out,(out EQ_U (C_TO_S{2}col/3)[2]) AND cout_en)
END.


FN LAST_BLK_COUNT = (bool:ck,t_reset:reset, bool:en,t_channel:channel,bool:line_finished) ->
                              (STRING[2]bit,[2]bool#x_en,y_en#):
BEGIN
   MAKE BASIC_COUNT : lsb msb.
JOIN  (ck,reset,en) ->lsb,
   (ck,reset, CASE channel
```

```
           OF y:lsb[2],
            u|v:line_finished
           ESAC) ->msb.
LET out = (msb[1]CONClsb[1]).
OUTPUT (out, CASE channel
         OF y:(out EQ_U (C_TO_S{2}col/3)[2],line_finished),
        u|v:(lsb[2],msb[2])
          ESAC)
END.
#the L1 norm calculator/ comparison constants& flag values#
#adding 4 absolute data values so result can grow by 2 bits#
#5 cycle sequence, a reset cycle with no data input, followed#
#by 4 data cycles#

MAC L1NORM = (bool:ck, t_reset:reset, STRING[INT n]bit:in) ->STRING[n+2]bit:
BEGIN
    MAKE DF1{STRING[n+4]bit}:in2.


LET in_s =in,
   msb = ALL_SAME{n}(B_TO_Sin_s[1]),
COM
   add_in1 = in2 CONC in_s[1],  #in_s[1] is the carryin to the adder#
                                 #,lsb so gen carry to next bit#
   add_in2 = ((in_s XOR_B msb)CONC in_s[1]),
   #adder=ADD_U(add_in1,add_in2),#
MOC
   add_in1 = (in_s XOR_B msb),
   rst_mux = CASE reset
          OF     rst:ZERO{n+4}b"0"
          ELSE in2
```

```
        ESAC,

    adder=ADD_US_ACTEL(add_in1,rst_mux,CASE in_s[1]
                OF b'1:b'0
                ELSE b'1
                ESAC ),
    out =adder[2..(n+5)].

JOIN  (ck,out)   ->in2.

OUTPUT in2[3..n+4]
END.

#the block to decide if all its inputs are all 0#
FN ALL_ZERO = (bool:ck, t_reset:reset, t_input:in)   ->bool:
BEGIN

   MAKE DF1{bool}:out.

LET in_s =(IN_TO_S{input_exp}in)[2],

   in_eq_0 = in_s EQ_U ZERO{input_exp}b"0",  #in =0#
#1 if reset high, & OR with previous flag#
   all_eq_0 = CASE reset
         OF rst:   in_eq_0
         ELSE CASE out
           OF   f:f
           ELSE in_eq_0
           ESAC
         ESAC.
```

```
JOIN  (ck,all_eq_0)->out.
OUTPUT out
END.

MAC ABS_NORM = (bool:ck, t_reset:reset,STRING[result_exp-2]bit:qshift, STRING[INT n]bit:in)
                              ->(STRING[n+2]bit,bool#all <qshift#):
BEGIN
    MAKE DF1{STRING[n+4]bit}:in2,
     DF1{bool}:out.
LET   abs_in = ABS_S in,
  rst_mux = CASE reset
        OF      rst:ZERO{n+4}b"0"
        ELSE  in2
        ESAC,

  adder = ADD_US_ACTEL(abs_in,rst_mux,b'1),
  add_s =adder[2..(n+5)],
  in_small = abs_in LT_U qshift,
#1 if reset high, & OR with previous flag#
   all_small =  CASE reset
         OF  rst:  t
         ELSE CASE in_small
        OF   f:f
        ELSE out
        ESAC
         ESAC.

 JOIN   (ck,add_s)   ->in2,
   (ck,all_small)  ->out.

 OUTPUT (in2[3..n+4],out)
```

```
END.


#the decide fn block#
FN DECIDE = (bool:ck,t_reset:reset,t_result:q_int,t_input:new old, t_result: threshold comparison,
            t_octave:octs,t_load:load_flags)        ->[7]bool:
#nzflag,origin,noflag,ozflag,motion,pro_new_z,pro_no_z#
BEGIN
   MAKE L1NORM{input_exp}: oz,
       ABS_NORM{input_exp}: nz,
       ABS_NORM{input_exp+1}:no,
       LATCH{[7]bool}:flags.

 LET    qshift=(I_TO_SC{result_exp}q_int)[2][1..result_exp-2].
 #divide by 4 as test is on coeff values not block values#

     n_o =(IN_TO_S{input_exp}new)[2] SUB_S  (IN_TO_S{input_exp}old)[2], #new-old,use from quant#
     nzflag = nz[1] LE_U (I_TO_SC{result_exp}threshold)[2],      #delay tests for pipelined data#
     noflag = no[1] LE_U (I_TO_SC{result_exp}comparison)[2],
     ozflag = oz EQ_U ZERO{input_exp}b"0",
     origin = nz[1] LE_U no[1],
     nz_plus_oz = nz[1] ADD_U oz,

     pro_new_z = nz[2],

     pro_no_z = no[2],

     shift_add_sel = CASE DF1{t_octave}(ck,octs)            #delay octs to match pipelin delay#
                 OF      oct/0:uno,
```

```
                        oct/1:dos,
                        oct/2:tres,
                        oct/3:quatro
                ESAC,
#keep 13 bits here to match no, keep msb's#
   shift_add= MUX_4{STRING[input_exp+3]bit}(          #delay octs to match pipelin delay#
                        nz_plus_oz[1..input_exp+3],
                        b"0"CONC nz_plus_oz[1..input_exp+2],
                        b"00"CONC nz_plus_oz[1..input_exp+1],
                        b"000"CONC nz_plus_oz[1..input_exp],
                        shift_add_sel
                        ),

   motion = shift_add LE_U no[1],
#value for simulation#
   nz_r = (SC_TO_I{12} nz[1])[2],
   no_r = (SC_TO_I{13} no[1])[2],
   oz_r = (SC_TO_I{12} oz)[2],
   sa_r = (SC_TO_I{13} shift_add)[2].


JOIN  (ck,reset,qshift,(IN_TO_S{input_exp}new)[2])  ->nz,
  (load_flags,(nzflag,origin,noflag,ozflag,motion,pro_new_z,pro_no_z)) ->flags,
  (ck,reset,qshift,CAST{ STRING[input_exp+1]bit}n_o) ->no,
  (ck,reset,(IN_TO_S{input_exp}old)[2])  ->oz.
OUTPUT flags
END.
#the buffer for the FIFO#

#a pulse generator, glitch free#
FN PULSE = (bool:ck,t_reset:reset,t_load:in)  ->t_load:
```

```
CASE (in,DFF{t_load}(ck,reset,in,read))
OF     (write,read):write
ELSE   read
ESAC.

#the length of the huffman encoded word#
FN LENGTH = (t_input:mag_out)          ->STRING[5]bit:
CASE mag_out          #length of inputoded word#
OF     input/0:b"00001",
       input/1:b"00011",
       input/2:b"00100",
       input/3:b"00101",
       input/4:b"00110",
       input/5:b"00111",
       input/6:b"01000",
       input/(7..21):b"01100"
 ELSE                b"10000"
 #      input/(22..37):b"10000"#
 ESAC.

FN REV_BITS = (STRING[8]bit:in)   ->STRING[8]bit:CAST{STRING[8]bit}(in[8],in[7],in[6],in[5],in[4],in[3],in[2],in[1]).

FN FIFO_BUFFER = (bool:ck, t_reset:reset,t_direction:direction,t_cycle:cycle,t_mode:mode,
        t_input:value mag_out_huff, STRING[16]bit:fifo_in,t_fifo:fifo_full fifo_empty,
         STRING[32]bit:shift,STRING[2]bit:token_length, bool:flush_buffer,t_quant:lpf_quant)

        ->(STRING[16]bit,STRING[16]bit,STRING[16]bit,STRING[5]bit,t_load,t_load):
#fifo_out, s, fifo_read fifo_write#

 BEGIN
    MAKEDFF_INIT{STRING[16]bit}:low_word high_word,
```

```
    DFF_INIT{STRING[5]bit}:s,
    DFF_INIT{t_high_low}:high_low,
    MUX_2{STRING[16]bit}:high_in low_in high_out low_out.


LET   dir_sel =     CASE direction
              OF    forward:left
              ELSE  right
              ESAC,

  length = CASE cycle
         OF   token_cycle:b"000" CONC token_length,
              skip_cycle:b"00000",
              data_cycle:   CASE mode  #on LPF_STILL length fixed, given by input_exp-shift const#
                        OF    lpf_still:((LEN_TO_U{5} len/input_exp)[2] SUB_U
                                (Q_TO_U{3} lpf_quant)[2])[2..6]
                        ELSE  LENGTH MUX_2{t_input}(value,mag_out_huff,dir_sel)
                        ESAC
         ESAC,

    select_s = CASE direction
           OF    forward:b"0" CONC s[2..5]
              ELSE   s
           ESAC,

    new_s = (ADD_US_ACTEL(select_s,length,b'1'))[2..6],       #6 bits#
 #if new s pointer >16#
 #on inverse passed first 16 bits, active from [16,31] #

     high_low_flag = new_s GE_U b"10000",
```

```
#forward#
  fifo_not_full = CASE   fifo_full
                  OF     ok_fifo: write
                  ELSE          read
                  ESAC,


   fifo_write = CASE high_low      #type change#
              OF  high:write
              ELSE      CASE flush_buffer           #flush buffer when frame finished#
                        OF      t:write             #needs 2 cycles to clear#
                        ELSE    CASE DFF{bool}(ck,reset,flush_buffer,f)
                                OF     t:write
                                ELSE   read
                                ESAC
                        ESAC
              ESAC,
#from inverse#

   data_ready =   CASE fifo_empty
                  OF     ok_fifo:write
                  ELSE   read
                  ESAC,


    load_low       =     CASE reset           #load low on reset to start things#
                   OF    rst:write,
                         no_rst: PULSE(ck,reset, CASE (high_low_flag,data_ready) #load low word#
                                 OF     (t,write):write
                                 ELSE   read
                                 ESAC)
```

```
                    ELSE read
                    ESAC,
#delay reset for s and load_high#
   reset_s =      DFF{t_reset}(ck,reset,reset,rst),

   load_high     =CASE reset_s    #load high next#
              OF     rst:write,
                 no_rst: PULSE(ck,reset, CASE (high_low_flag,data_ready) #load high word#
                   OF     (f,write):write
                    ELSE    read
                    ESAC)
               ELSE read
               ESAC,

   fifo_read      = CASE load_low        #read control for data_in FIFO#
               OF    write:read
               ELSE  CASE load_high
                 OF     write:read
                 ELSE    write
                 ESAC
               ESAC,

 #control signals#

 (write_low,write_high) =CASE direction
               OF      forward:[2]fifo_not_full
               ELSE    (load_low,load_high)
               ESAC,

 (high_out_sel,low_out_sel) =   CASE direction
                  OF     forward:CASE high_low
```

```
                OF     high:(left,right)
                ELSE   (right,left)
                ESAC

        ELSE   [2]CAST{t_mux}(s GE_U b"10000")
        ESAC.

JOIN
    (shift[17..32],fifo_in,dir_sel)          ->high_in ,

    (shift[1..16],fifo_in,dir_sel)           ->low_in,

    (high_word,low_word,high_out_sel)        ->high_out,

    (low_word,high_word,low_out_sel)         ->low_out,

    (ck,reset,write_low,low_in,ZERO{16}b"0")  ->low_word,

    (ck,reset,write_high,high_in,ZERO{16}b"0")    ->high_word,

    (ck,reset,fifo_not_full,CASE high_low_flag
            OF    t:high
            ELSE  low
            ESAC,low)          ->high_low,

    (ck,CASE forward
       OFforward:reset
       ELSE reset_s
       ESAC,CASE direction
          OF  forward:fifo_not_full
```

```
        ELSE data_ready
        ESAC,       new_s,ZERO{5}b"0")   ->s.

OUTPUT (low_word,low_out,high_out,s,fifo_read,fifo_write)
END.
#the HUFFMAN decode/encode function#

#a pulse generator, glitch free#

FN PULSE = (bool:ck,t_reset:reset,t_load:in)  ->t_load:
 CASE (in,DFF{t_load}(ck,reset,in,read))
 OF     (write,read):write
 ELSE   read
 ESAC.



FN SHIFT32_16 = (STRING[32]bit:buffer,STRING[5]bit:s)       ->STRING[16]bit:
#left justified value, s shift const#
BEGIN
LET shift = (s AND_B b"01111")[2..5].       #Input values rotated so always shift<16#
OUTPUT
CAST{STRING[16]bit}([INT j=1..16] MX16(CAST{STRING[16]bit}([INT i=1..16]buffer[j-1+i]),shift) )
END.

FN SHIFT16X16_32 = (STRING[16]bit:o n, STRING[4]bit:sel)   ->STRING[32]bit:
BEGIN
LET sel_mux4= CASE sel[1..2]
        OFb"00":sel[3..4]
        ELSE b"11"
```

```
        ESAC,
sel_mux4_high = CASE sel[1..2]
            OF      b"11":sel[3..4]
            ELSE    b"00"
            ESAC,
sel_mux8 =  CASE sel[1]
        OF b'0: sel[2..4]
        ELSE b"111"
        ESAC,
sel_mux8_high =  CASE sel[1]
            OF b'1: sel[2..4]
            ELSE b"000"
            ESAC.
OUTPUT CAST{STRING[32]bit}(
 MX_4{bit}(n[1],o[1],o[1],o[1],CAST{[2]bool}sel_mux4),
 MX_4{bit}(n[2],n[1],o[2],o[2],CAST{[2]bool}sel_mux4),
 MX_4{bit}(n[3],n[2],n[1],o[3],CAST{[2]bool}sel_mux4),

 MUX_8{bit}(n[4],n[3],n[2],n[1],o[4],o[4],o[4],o[4],CAST{[3]bool}sel_mux8),
 MUX_8{bit}(n[5],n[4],n[3],n[2],n[1],o[5],o[5],o[5],CAST{[3]bool}sel_mux8),
 MUX_8{bit}(n[6],n[5],n[4],n[3],n[2],n[1],o[6],o[6],CAST{[3]bool}sel_mux8),
 MUX_8{bit}(n[7],n[6],n[5],n[4],n[3],n[2],n[1],o[7],CAST{[3]bool}sel_mux8),

MX16(CAST{STRING[8]bit}(([INT I=1..8]n[9-I]) CONC ALL_SAME{8}B_TO_S o[8],sel[1..4]),
MX16(CAST{STRING[9]bit}([INT I=1..9]n[10-I]) CONC ALL_SAME{7}B_TO_S o[9],sel[1..4]),
MX16(CAST{STRING[10]bit}([INT I=1..10]n[11-I]) CONC ALL_SAME{6}B_TO_S o[10],sel[1..4]),
MX16(CAST{STRING[11]bit}([INT I=1..11]n[12-I]) CONC ALL_SAME{5}B_TO_S o[11],sel[1..4]),

MX16(CAST{STRING[12]bit}([INT I=1..12]n[13-I]) CONC ALL_SAME{4}B_TO_S o[12],sel[1..4]),
MX16(CAST{STRING[13]bit}([INT I=1..13]n[14-I]) CONC ALL_SAME{3}B_TO_S o[13],sel[1..4]),
MX16(CAST{STRING[14]bit}([INT I=1..14]n[15-I])CONC ALL_SAME{2}B_TO_S o[14],sel[1..4]),
```

```
MX16(CAST{STRING[16]bit}(([INT i=1..15]n[16-i])CONC o[15]),sel[1..4]),

MX16(CAST{STRING[16]bit}([INT i=1..16]n[17-i]),sel[1..4]),

MX16(CAST{STRING[16]bit}(b'0 CONC ([INT i=1..15]n[17-i])),sel[1..4]),
MX16(ZERO{2}b"0" CONC CAST{STRING[14]bit}([INT i=1..14]n[17-i]),sel[1..4]),
MX16(ZERO{3}b"0" CONC CAST{STRING[13]bit}([INT i=1..13]n[17-i]),sel[1..4]),
MX16(ZERO{4}b"0" CONC CAST{STRING[12]bit}([INT i=1..12]n[17-i]),sel[1..4]),

MX16(ZERO{5}b"0" CONC CAST{STRING[11]bit}([INT i=1..11]n[17-i]),sel[1..4]),
MX16(ZERO{6}b"0" CONC CAST{STRING[10]bit}([INT i=1..10]n[17-i]),sel[1..4]),
MX16(ZERO{7}b"0" CONC CAST{STRING[9]bit}([INT i=1..9]n[17-i]),sel[1..4]),
MX16(ZERO{8}b"0" CONC CAST{STRING[8]bit}([INT i=1..8]n[17-i]),sel[1..4]),

MUX_8{bit}(b'0,n[16],n[15],n[14],n[13],n[12],n[11],n[10],CAST{[3]bool}sel_mux8_high),
MUX_8{bit}(b'0,b'0,n[16],n[15],n[14],n[13],n[12],n[11],CAST{[3]bool}sel_mux8_high),
MUX_8{bit}(b'0,b'0,b'0,n[16],n[15],n[14],n[13],n[12],CAST{[3]bool}sel_mux8_high),
MUX_8{bit}(b'0,b'0,b'0,b'0,n[16],n[15],n[14],n[13],CAST{[3]bool}sel_mux8_high),

MX_4{bit}(b'0,n[16],n[15],n[14],CAST{[2]bool}sel_mux4_high),
MX_4{bit}(b'0,b'0,n[16],n[15],CAST{[2]bool}sel_mux4_high),
MX_4{bit}(b'0,b'0,b'0,n[16],CAST{[2]bool}sel_mux4_high),

b'0
  )
END.

MAC REV_4 = (STRING[4]bit:in)        ->STRING[4]bit:CAST{STRING[4]bit}((in[4],in[3],in[2],in[1])).

#in is data from bus, fifo_empty is input fifo control#
FN HUFFMAN_DECODE =(t_mode:mode,STRING[2]bit:token_length_in,STRING[32]bit:buffer,STRING[5]bit:s)
```

```
            ->(bit,t_input,STRING[2]bit#token#):
BEGIN

   MAKE SHIFT32_16:input_decode.
COM
LET   mag_out2 = CASE input_decode[9..12]
         OFb"1111":(input_decode[13..16] ADD_U b"10110")#add 22 to give value#
         ELSE input_decode[9..12] ADD_U b"00111"      #add 7 to give value#
         ESAC,
MOC
LET   sel_9_12 =    CASE input_decode[9..12]
              OF    b"1111":t
         ELSE f
              ESAC,
   mag_out2 = CASE sel_9_12
        OF  t:REV_4 input_decode[13..16]
        ELSE  REV_4    input_decode[9..12]
        ESAC      ADD_U
                CASE sel_9_12
                OFt: b"10110"       #add 22 to give value#
                ELSE b"00111"       #add 7 to give value#
                ESAC,

  mag_out_huff=CASE input_decode[1]
       OFb'0:input/0
       ELSE CASE input_decode[3]
          OFb'1:input/1
          ELSE CASE input_decode[4]
             OFb'1:input/2
             ELSE CASE input_decode[5]
                   OF     b'1:input/3
```

```
                ELSE CASE input_decode[6]
                OF b'1:input/4
                ELSE CASE input_decode[7]
                    OFb'1:input/5
                    ELSE CASE input_decode[8]
                        OFb'1:input/6
                        ELSE (S_TO_IN (b"0000" CONC mag_out2))[2]
                        ESAC
                    ESAC
                ESAC
            ESAC
        ESAC
    ESAC
ESAC,

#on lpf_still bit 1 is the sign bit#
    sign = CASE mode
        OFlpf_still:input_decode[1]
        ELSE CASE mag_out_huff
            OFinput/0:b'0
            ELSE input_decode[2]
            ESAC
        ESAC,

#select huff value, 0(in lpf_send) or real value, rearange the bits for real data#
#on lpf_still bit 1 is sign bit so discard#
    mag_out = CASE mode
        OF   lpf_still:(S_TO_IN (CAST{STRING[9]bit}[INT j=1..9]input_decode[11-j]))[2]
        ELSE mag_out_huff
        ESAC,
```

```
    token_length = b"000"CONC token_length_in,

#decode token, valid only during a token cycle#
      token = CASE token_length[4..5]
        OFb"10":input_decode[1..2],
            b"01":input_decode[1] CONC b"0"
        ESAC.

JOIN   (buffer,s)     ->input_decode.

OUTPUT (sign,mag_out,token)
END.


#the huffman encoder#
FN HUFFMAN_ENCODE = (t_input:value,bit:sign,STRING[2]bit:token,t_mode:mode, t_cycle:cycle,
                STRING[16]bit:buffer,STRING[5]bit:s)
                            ->(STRING[32]bit):
BEGIN
    MAKE     SHIFT16X16_32:shift.
#encode value#
LET    header = CAST{STRING[2]bit}(b'1,sign),

    value_bit = CAST{[16]bit}(IN_TO_S{16} value)[2],

    sub_const = CASE value
          OF  input/(7..21):b"00111",
            input/(22..37):b"10110"
           ELSE  b"00000"
         ESAC,
```

```
    sub_value = ((IN_TO_S{input_exp}value)[2] SUB_U sub_const)[8..11],

enc_value=

 CASE cycle
 OF    token_cycle:token CONC ZERO{14}b"0",    #token is msb, max 2 bits#
    data_cycle: CASE mode
#on intra & LPF pass thro value as 16 bit word, and reverse bit order, place sign first next to lsb#
      OF   lpf_still:CAST{STRING[1]bit} sign CONC CAST{STRING[15]bit} ([INT j=1..15]value_bit[17-j])
#otherwise value is to Huffman encoded, so out 16 bit as this is the max, the shift removes the extra bits#
      ELSE    CASE value
        OF    input/0:b"0"CONC ZERO{15}b"0",
           input/1:header CONC b"1"CONC ZERO{13}b"0",
           input/2:header CONC b"01"CONC ZERO{12}b"0",
           input/3:header CONC b"001"CONC ZERO{11}b"0",
           input/4:header CONC b"0001"CONC ZERO{10}b"0",
           input/5:header CONC b"00001"CONC ZERO{9}b"0",
           input/6:header CONC b"000001"CONC ZERO{8}b"0",

           input/(7..21):header CONC b"000000" CONC(REV_4 sub_value)CONC ZERO{4}b"0",     #sub 7 to give value#

           input/(22..37):header CONC b"0000001111" CONC (REV_4 sub_value)          #sub 22 to give value#

           ELSE header CONC b"00000011111111"
           ESAC

      ESAC,

      skip_cycle:ZERO{16}b"0"     #dummy value#
    ESAC.
```

```
JOIN  (buffer ,enc_value,s[2..5])      ->shift.


#max value is 37 so 8 bits enough#
OUTPUT shift
END.


# some basic macros for the convolver, assume these will#
#be synthesised into leaf cells#
MAC  MX_4{TYPE ty}=(ty:in1 in2 in3 in4, [2]bool:sel)      ->ty:
CASE    sel
OF     (f,f):in1,
       (f,t):in2,
       (t,f):in3,
       (t,t):in4
ESAC.

MAC ENCODE4_2 = (t_mux4:in)     ->[2]bool:
CASE in
OF      uno:(f,f),
        dos:(f,t),
        tres:(t,f),
        quatro:(t,t)
ESAC.

MAC ENCODE3_2 = (t_mux3:in)     ->[2]bool:
CASE in
OF      l:(f,f),
        c:(f,t),
```

```
    r:(t,f)
ESAC.

MAC MUX_3{TYPE t}=(t:in1 in2 in3 , t_mux3:sel) ->t:
MX_4{t}(in1,in2,in3,in1,ENCODE3_2 sel).

MAC MUX_4{TYPE t}=(t:in1 in2 in3 in4, t_mux4:sel)     ->t:
MX_4{t}(in1,in2,in3,in4,ENCODE4_2 sel).


MAC MUX_2{TYPE t}=(t:in1 in2, t_muxsel)   ->t:
CASE sel
OF    left:in1,
   right:in2
ESAC.

MAC MUX_8{TYPE ty}=(ty:in1 in2 in3 in4 in5 in6 in7 in8, [3]bool:sel) ->ty:
CASE sel
OF     (f,f,f):in1,
   (f,f,t):in2,
     (f,t,f):in3,
     (f,t,t):in4,
     (t,f,f):in5,
     (t,f,t):in6,
     (t,t,f):in7,
     (t,t,t):in8
ESAC.
MAC MX16=(STRING[16]bit:in, STRING[4]bit:sel)   ->bit:
CASE sel
OF     b"0000":in[1],
       b"0001":in[2],
```

```
    b"0010":in[3],
    b"0011":in[4],
    b"0100":in[5],
    b"0101":in[6],
    b"0110":in[7],
    b"0111":in[8],
    b"1000":in[9],
    b"1001":in[10],
    b"1010":in[11],
    b"1011":in[12],
    b"1100":in[13],
    b"1101":in[14],
    b"1110":in[15],
    b"1111":in[16]
ESAC.
COM
MAC MX16=(STRING[16]bit:in, STRING[4]bit:sel)  ->bit:
MUX_2{bit}(
    MUX_8{bit}(in[1],in[2],in[3],in[4],in[5],in[6],in[7],in[8],CAST{[3]bool}sel[2..4]),
    MUX_8{bit}(in[9],in[10],in[11],in[12],in[13],in[14],in[15],in[16],CAST{[3]bool}sel[2..4]),
    CASE sel[1]
    OF  b'0:left
    ELSE right
    ESAC).
 MOC

 MAC INT_BOOL = (t_quant:q)    ->[3]bool:
 CASE q
 OF     quant/0:(f,f,f),
      quant/1:(f,f,t),
      quant/2:(f,t,f),
```

```
      quant/3:(f,t,t),
      quant/4:(t,f,f),
      quant/5:(t,f,t),
      quant/6:(t,t,f),
      quant/7:(t,t,t)
ESAC.

COM
MAC  MUX_3{TYPE t}=(t:in1 in2 in3, t_mux3:sel) ->t:
CASE sel
OFl:in1,
    c:in2,
    r:in3
ESAC.

MAC  MUX_4{TYPE t}=(t:in1 in2 in3 in4, t_mux4:sel) ->t:
CASE sel
OFuno:in1,
    dos:in2,
    tres:in3,
    quatro:in4
ESAC.
MOC

FN NOT = (bool:in)->bool:CASE in OF t:f,f:t ESAC.

FN XOR = (bool: a b)   ->bool:
CASE (a,b)
OF  (f,f)|(t,t):f
ELSE t
ESAC.
```

```
JOIN in->del.
OUTPUT del
END.


#a resetable DFF, init value is input parameter#
MAC DFF_INIT{TYPE t}=(bool:ck,t_reset:reset,t_load:load,t:in init_value)    ->t:
BEGIN
MAKE DEL{t}:del.
LET out=CASE (load,reset)
      OF    (write,t_reset):in,
            (read,rst):init_value
      ELSE  del
      ESAC.
JOIN out->del.
OUTPUT CASE reset
      OF rst:init_value
      ELSE    del
      ESAC
END.

#a dff resetable non- loadable dff#
MAC DFF{TYPE t}=(bool:ck,t_reset:reset,t:in init_value)    ->t:
BEGIN
MAKE DEL{t}:del.
JOIN in->del.
OUTPUT CASE reset
      OF rst:init_value
      ELSE    del
      ESAC
END.
```

```
MAC PDEL{TYPE t,INT n} = (t:in) ->t:
      IF n=0 THEN DEL{t}in
      ELSE   PDEL{t,n-1} DEL{t} in
      FI.

MAC PDF1{TYPE t,INT n} = (bool:ck,t:in ) ->t:
      IF n=0 THEN DF1{t}(ck,in)
      ELSE   PDF1{t,n-1}(ck,DF1{t}(ck, in))
      FI.
#generates the new_mode from the old, and outputs control signals to the tokeniser#

FN MODE_CONTROL = (bool:ck, t_reset:reset, t_intra:intra_inter,bool:lpf_done,[7]bool:flags,
        STRING[2]bit:token_in,t_octave:octave,t_state:state,t_direction:direction,t_load:load_mode_in
        ,t_cycle:cycle)
                ->(t_mode,t_mode,STRING[2]bit,t_diff,STRING[2]bit,t_mode):
#new_mode,proposed mode,current token,difference,token_length, #
BEGIN

     MAKE [4]DFF_INIT{t_mode}:mode,
          DFF_INIT{t_diff}:diff_out,
          DFF_INIT{t_mode}:next_mode.
LET    nzflag=flags[1],
     origin=flags[2],
     noflag=flags[3],
     ozflag=flags[4],
     motion=flags[5],
     pro_new_z = flags[6],
     pro_no_z = flags[7],
```

```
   lpf_done_del = DFF{bool}(ck,reset,lpf_done,f).         #synchronise mode change at end of LPF#

LET next = (SEQ
#the proposed value for the mode at that octave, flags etc will change this value as necessary#
#proposed, or inherited mode from previous tree#

          VAR    pro_mode:= CASE reset
                    OF   rst:CASE intra_inter     #reset on frame start, so do lpf#
                          OF intra:lpf_still
                          ELSE lpf_send
                          ESAC
                    ELSE  CASE lpf_done_del
                OFt:CASE intra_inter    #store default mode in mode[4]#
                              OF intra:still
                              ELSE send
                              ESAC

                ELSE CASE state
                    OFdown1:mode[3], #jump sideways in oct/1#
                    ,  up0:mode[4]
                    ELSE CASE octave
                        OF     oct/0:mode[1],
                            oct/1:mode[2],
                            oct/2:mode[3]
                        ESAC
                    ESAC
                ESAC

               ESAC,
          new_mode:=pro_mode,          #inherit the previous mode#
          token_out:=b"00",
```

```
        difference:=nodiff,
        token_length:=b"00",
        flag:=f;
CASE direction
OF forward:

 CASE pro_mode
 OFvoid:CASE ozflag
        OF   t:new_mode:=stop
        ELSE
        ESAC,              #stay in these modes until end of tree#

    void_still: ,                #intra so must zero out all of tree#

     still_send:(token_length:=b"01";
                CASE (nzflag OR pro_new_z)
                 OF  t:(token_out:=b"00";
                        CASE ozflag
                        OF    t:new_mode:=stop
                        ELSE   new_mode:=void
                        ESAC)
                 ELSE (token_out:=b"10";
                     new_mode:=still_send)
                 ESAC
      ),

    send:  CASE ozflag
      OFt:(token_length:=b"01";

         CASE (nzflag OR pro_new_z )
```

```
    OF   t:(token_out:=b"00";
         new_mode:=stop)
    ELSE    (token_out:=b"10";
        new_mode:=still_send)
    ESAC
    )
ELSE (token_length:=b"10";

    CASE ( (NOTnoflag OR motion) AND NOTnzflag)
    OFt:( CASE origin
          OF    t:flag:=pro_new_z
          ELSE (flag:=pro_no_z;
              difference:=diff)
          ESAC;
        CASE flag
        OFt:(token_out:=b"10";
            new_mode:=void)
        ELSE     CASE origin
                OFt:(token_out:=b"01";
                      new_mode:=still_send)
                ELSE (token_out:=b"11";
                     new_mode:=send)
                ESAC
        ESAC)
    ELSE

        CASE (motion OR origin)AND nzflag
        OFt:(token_out:=b"10";
             new_mode:=void)
        ELSE (token_out:=b"00";
            new_mode:=stop)
```

```
            ESAC
          ESAC
          )
        ESAC,


    still:   (token_length:=b"01";
        CASE (nzflag OR pro_new_z)
        OFt:(token_out:=b"00";
                   new_mode:=void_still)   #zero out tree#
        ELSE (token_out:=b"10";
                   new_mode:=still)
        ESAC
        ),

    (lpf_still):(token_out:=b"00";          #for ELLA only DUMB!!#
          token_length:=b"00"),

    (lpf_send):(difference:=diff;
          token_length:=b"01";

          CASE (noflag OR pro_no_z)
                OF     t:(token_out:=b"00";
                new_mode:=lpf_stop)
          ELSE (token_out:=b"10";
                new_mode:=lpf_send) #as mode stop but for this block only#
          ESAC)
    ESAC,

inverse:
    CASE pro_mode
```

```
OF void: CASE ozflag
        OF   t:new_mode:=stop
        ELSE
        ESAC,

    void_still: ,

    send:  CASE ozflag
        OFt:(token_length:=b"01";      #repeat of still-send code#
                    CASE token_in[1]
                    OF      b'1:new_mode:=still_send,
                          b'0:new_mode:=stop
                    ESAC
                    )

        ELSE (token_length:=b"10";
            CASE token_in
            OFb"11": (difference:=diff;
                    new_mode:=send),
                b"01":new_mode:=still_send,
                b"10":new_mode:=void,
                b"00":new_mode:=stop
            ESAC
            )
        ESAC,

    still_send:     (token_length:=b"01";
            CASE token_in[1]
            OFb'1:new_mode:=still_send,
                b'0:    CASE ozflag
                    OFt:new_mode:=stop
```

```
                ELSE new_mode:=void
                ESAC
            ESAC
            ),

    still:  (token_length:=b"01";
        CASE token_in[1]
                OF    b'1:new_mode:=still,
                      b'0:new_mode:=void_still
                ESAC
            ),


  (lpf_send):(difference:=diff;
         token_length:=b"01";
           CASE token_in[1]
                OF    b'0:new_mode:=lpf_stop,
              b'1:new_mode:=lpf_send
           ESAC),

    lpf_still:
  ESAC

ESAC;

OUTPUT (new_mode,pro_mode,token_out,difference,token_length)
).

LET load_mode = CASE (reset,lpf_done_del) #store base mode in mode[3]& mode[4], base changes after lpf#
          OF    (rst,bool)|(t_reset,t):(read,read,write,write)
          ELSE  CASE (octave,load_mode_in)
```

```
                OF     (oct/1,write):(write,write,read,read),
                       (oct/2,write):(read,write,write,read)
                ELSE (read,read,read,read)
                ESAC
           ESAC.
#save the new mode& difference during a token cycle, when the flags and tokens are valid#
JOIN      (ck,reset,CASE cycle
        OF    token_cycle:write
        ELSEread
        ESAC, next[1],still)              ->next_mode,

          (ck,reset,CASE cycle
           OF    token_cycle:write
           ELSE  read
           ESAC, next[4],nodiff)                    ->diff_out.


#now write the new mode value into the mode stack at end of cycle, for later use #
FOR INT i =1..4 JOIN  (ck,no_rst,load_mode[i],CASE (reset,lpf_done_del)
                      OF(no_rst,t)|(rst,bool):next[2]
                      ELSE next_mode
                      ESAC,still)   ->mode[i].
#dont update modes at tree base from lpf data, on reset next[1] is undefined#

OUTPUT (next_mode,next[2],next[3],diff_out,next[5],next[1])
END.

#the tree coder chip#
#threshold = 2^quant_norm#

FN PALMAS= (bool:ck,t_reset:reset,t_direction:direction,t_intra:intra_inter,t_channel_factor:channel_factor,
```

```
   [4]t_quant:quant_norm, STRING[16]bit:buffer_in,
    t_input:new old,[4]t_result:threshold, t_fifo:fifo_full fifo_empty, STRING[xsize]bit:col_length,
   STRING[ysize]bit:row_length,STRING[xsize]bit:ximage_string,#ximage#
    STRING[ysize]bit:yimage_string,STRING[11]bit:yimage_string_3#yimage& yimage*2.5#)

   ->(t_input,t_sparc_addr,(t_load,t_cs),(t_load,t_cs),STRING[16]bit,[2]t_load,bool,t_cycle):

#old,address,(rw_new,cs_new),(rw_old,cs_old),buffer_out,fifo_read fifo_write, cycle#

BEGIN
   MAKEDECIDE:decide,
      ADDR_GEN:addr_gen,
      HUFFMAN_ENCODE:huffman_encode,
      FIFO_BUFFER:fifo_buffer,
      HUFFMAN_DECODE:huffman_decode,
      MODE_CONTROL:mode,
      CONTROL_COUNTER:control_counter,
      BLK_SUB_COUNT: sub_count,
      DFF_INIT{t_channel}:channel,
      QUANT:quant.

LET

   nzflag=decide[1],
   origin=decide[2],
   noflag=decide[3],
   ozflag=decide[4],
   motion=decide[5],
   pro_no_z = decide[7],#pro_no_z or pro_new_z#
   pro_new_z = decide[6],
```

```
new_mode = mode[1],
pro_mode = mode[2],
token_out = mode[3],
difference = mode[4],
token_length = mode[5],

pro    =quant[1],    #pro_no, or pro_new#
lev_out = (S_TO_IN quant[2])[2], #corresponding level#
sign = quant[3],  #and sign #

octs = addr_gen[2],
sub_en = addr_gen[3],
tree_done = addr_gen[4],
lpf_done = addr_gen[5],
state = addr_gen[6],

cycle =control_counter[2],
cs_new=control_counter[7],
rw_new=read,
rw_old=control_counter[8],
cs_old=control_counter[9],

load_channel= CASE (sub_en,sub_count[2])  #change channel#
        OF(t,t):write
        ELSE read
        ESAC,

new_channel = CASE channel_factor
            OF    luminance:y
            ELSE   CASE channel
                OF     y:u,
```

```
                    u:v,
                    v:y
                 ESAC
              ESAC,
#flush the buffer in the huffman encoder#
  flush_buffer =DFF{bool}(ck,reset,CASE channel_factor
              OFluminance:CASE load_channel
                    OF   write:t
                    ELSE    f
                    ESAC,
                color: CASE (channel,load_channel)
                   OF(v,write):t
                   ELSE f
                   ESAC
              ESAC,f),

  frame_done = PDF1{bool,1}(ck,flush_buffer),

  fifo_write=fifo_buffer[6],
  fifo_read =fifo_buffer[5],
  s =fifo_buffer[4],

  buffer_out = fifo_buffer[1],

   lev_in = huffman_decode[2],
   sign_in = huffman_decode[1],
   token_in = huffman_decode[3],

  del_new = PDF1{t_input,4}(ck,new),
```

```
#old has variable delays for inverse#
   del_old = CASE (direction,pro_mode)
       OF   (forward,t_mode)|(inverse,send|still_send|lpf_send|void): PDF1{t_input,4}(ck,old)
       ELSE    PDF1{t_input,1}(ck,old)
       ESAC,
   decide_reset=CASE reset
            OF rst:rst
          ELSE  control_counter[3]
          ESAC,

   oct_sel = CASE pro_mode
          OFlpf_still|lpf_send|lpf_stop:quatro
          ELSE CASE (octs,channel)
             OF(oct/0,y):uno,
                (oct/1,y)|(oct/0,u|v):dos,
                (oct/2,y)|(oct/1,u|v):tres
             ESAC
          ESAC,

   threshold_oct = MUX_4{t_result}(threshold[1],threshold[2],threshold[3],threshold[4],oct_sel),

   quant_oct = MUX_4{t_quant}(quant_norm[1],quant_norm[2],quant_norm[3],quant_norm[4],oct_sel).

JOIN  (ck,decide_reset,threshold_oct,new,old,threshold_oct,threshold_oct,octs,control_counter[6])->decide,

(ck,reset,intra_inter,lpf_done,decide,token_in,octs,state,direction,control_counter[1],cycle)->mode,

#delay the new&old values by 5 or 1 depending on mode & direction#
   ( (IN_TO_S{input_exp}del_new)[2], (IN_TO_S{input_exp}del_old)[2],
   (IN_TO_S{input_exp}lev_in)[2], sign_in,direction,quant_oct,difference,pro_mode)  ->quant,
```

```
  (ck,reset ,new_channel,channel,load_channel,sub_count[1],col_length,row_length,
  ximage_string,yimage_string,yimage_string_3,control_counter[4],control_counter[5],new_mode)->addr_gen,

  (ck,reset,direction,cycle,pro_mode,lev_out,huffman_decode[2],buffer_in,fifo_full,
  fifo_empty,huffman_encode, token_length, flush_buffer,quant_norm[4])          ->fifo_buffer,

  (lev_out ,sign,token_out,pro_mode,cycle,fifo_buffer[2],s)          ->huffman_encode,

   (pro_mode,token_length,fifo_buffer[2] CONC fifo_buffer[3],fifo_buffer[4])      ->huffman_decode,

  (ck,reset,sub_en,t,t)                    ->sub_count,

  (ck,reset,pro_mode,new_mode,direction)              ->control_counter,

  (ck,reset,load_channel,new_channel,y)            ->channel.
OUTPUT

  ( CASE new_mode
   OF   void|void_still:input/0
   ELSE    (S_TO_INpro)[2]
   ESAC           ,addr_gen[1],(rw_new,cs_new),(rw_old,cs_old),buffer_out,(fifo_read,fifo_write),frame_done,cycle)
END.
COM
#the decoder for the barrel shifter-- decides if the bit value and q value are   #
#in the upper-triangle, or diagonal and set the control bits             #

MAC DECODE{INT n} = (t_quant:q)     ->[qmax](bool#upper diag#,bool#diagonal#):
BEGIN
   #one bit of the decoder#
   MAC  DECODE_BIT{INT j}= (t_quant:q)    ->(bool,bool):
   CASE q
```

```
MAC BARREL_SHIFT_RIGHT = (t_quant:q,STRING[INT n]bit:data) ->(STRING[n]bit#level#):
MUX_8{STRING[n]bit}(
      data,
      b"0"CONC data[1..n-1],
      b"00"CONC data[1..n-2],
      b"000"CONC data[1..n-3],
      b"0000"CONC data[1..n-4],
      b"00000"CONC data[1..n-5],
      b"000000"CONC data[1..n-6],
      b"0000000"CONC data[1..n-7],
      INT_BOOL q).

#the bshift for the inverse, to generate the rounded level #
MAC BARREL_SHIFT_LEFT = (t_quant:q,STRING[INT n]bit:data#lev#) ->(STRING[n]bit#round_level#):
MUX_8{STRING[n]bit}(
      data,
      data[2..n]CONCb"0",
      data[3..n]CONCb"01",
      data[4..n]CONCb"011",
      data[5..n]CONCb"0111",
      data[6..n]CONCb"01111",
      data[7..n]CONCb"011111",
      data[8..n]CONCb"0111111",
      INT_BOOL q).

#the function to return the quantised level(UNSIGNED), and proposed value given,#
# the new&old values, forw/inverse direction   #

FN QUANT = (STRING[input_exp]bit: new old lev_inv,bit:sign_lev_inv, t_direction:direction,t_quant:q,t_diff:difference,
         t_mode:mode)
```

```
        -> (STRING[input_exp]bit,STRING[input_exp]bit,bit) #pro,lev& sign# :

BEGIN

LET
#decide which of new-old or new will be quantised, and the sign of the level#
#level is stored in sign &magnitude form#

   dir_sel =    CASE direction
                OF    forward:left,
                      inverse:right
                ESAC,

   sub_sel = CASE difference
             OF    diff:left
             ELSE  right      #put old=0#
             ESAC,

  sub_in= MUX_2{STRING[input_exp]bit}(old,ZERO{input_exp}b"0",sub_sel),


  no =ADD_SUB_ST(new,sub_in,subt),

  lev_final= ABS_S no,      #now input_exp+1 bits#

   sgn_level = MUX_2{bit}( #sign of value to be quantised#
               no[1],
               sign_lev_inv,
               dir_sel).
```

```
#find the quant. level by shifting by q, for the inverse it comes from the Huffman decoder#

LET
   lev_data = BARREL_SHIFT_RIGHT(q,lev_final),

#saturate the lev at 37, for the Huffman table,except in lpf_still mode, send all the bits#
   lev_forw = CASE mode
        OF  lpf_still:lev_data
        ELSE   CASE lev_data GT_U b"00000100101"
          OFt:b"00000100101"
          ELSE lev_data
          ESAC
        ESAC,

   lev = MUX_2{STRING[input_exp+1]bit}(
              lev_forw,
              b"0" CONC lev_inv,
          dir_sel),
#the level = 0 flag#
     lev_z = lev EQ_U ZERO{input_exp+1}b"0",

   inv_lev_z =  CASE lev_z
             OF t:b'0
               ELSE b'1
          ESAC,

#the level value shifted up, and rounded#
      round_lev = BARREL_SHIFT_LEFT(q,lev) AND_B
            CASE mode
             OF  lpf_still:b"00" CONC ALL_SAME{input_exp-1}b"1"
             ELSE       BIT_STRING{input_exp+1}([input_exp+1]inv_lev_z) #if lev==0 out all 0's#
```

```
            ESAC,
#clear out extra bit for lpf_still case#


#calculate the proposed value:in the case n-o,round_lev is unsigned 10 bit, so result needs 11 bits#
#pro_no will always be in range as round_lev<|n-o|        #

  pro_no = ADD_SUB_ST(old,round_lev,CASE sgn_level
                OFb'0:add,
                   b'1:subt
                ESAC),

#now pro_new = +/- round_lev#

  round_sel = CASE sgn_level
          OFb'0: left,
             b'1: right
          ESAC,

    pro_new = MUX_2{STRING[input_exp+1]bit}(
          round_lev ,
          (NEG_U round_lev)[2..input_exp+2],     #NEG sign extends#
      round_sel),

   out_sel = CASE difference
       OFdiff:left
       ELSE right
       ESAC.


 OUTPUT (MUX_2{STRING[input_exp]bit}(
```

```
                pro_no[3..input_exp+2],
                pro_new[2..input_exp+1],
                out_sel) ,
        lev[2..input_exp+1] ,
        sgn_level)


END.
#actel 1 bit full adder with active low cin and cout#
FN FA1B = (bit: ain bin cinb)     ->(bit,bit):#cob,s#
BEGIN
LET     a_c =B_TO_S ain CONC NOT_B(B_TO_S cinb) ,
        b_c = B_TO_S bin CONC NOT_B(B_TO_S cinb) ,
      out = ADD_U(a_c,b_c).
OUTPUT(CAST{bit} NOT_B(B_TO_S out[1]), out[2])
END.


#a Ripple carry adder using 1 bit full adder blocks#

#the actel version of the ADD BIOP's#

MAC ADD_S_ACTEL = (STRING[INT m]bit:ain,STRING[INT n]bit:bin,bit:cinb) ->STRING[IF m>=n THEN m+1 ELSE n+1 FI]bit:
BEGIN
      MAKE [IF m>=n THEN m ELSE n FI]FA1B:sum.

#signed nos so sign extend #
 LET a_c = IF m>=n THEN ain ELSE ALL_SAME{n-m}B_TO_S ain[1]  CONC ain FI,
          b_c = IF n>=m THEN bin ELSE ALL_SAME{m-n}B_TO_S bin[1] CONC bin  FI.
      LET subsignal = sum.
#lsb#
```

```
JOIN   (a_c[IF m>=n THEN m ELSE n FI],b_c[IF m>=n THEN m ELSE n FI],cinb)    ->sum[IF m>=n THEN m ELSE n FI].

FOR INT j=1..(IF m>=n THEN m ELSE n FI) -1
JOIN (a_c[(IF m>=n THEN m ELSE n FI) -j],b_c[(IF m>=n THEN m ELSE n FI) -j],
     sum[(IF m>=n THEN m ELSE n FI) -j+1][1])              ->sum[(IF m>=n THEN m ELSE n FI) -j].

OUTPUT  CAST{STRING[IF m>=n THEN m+1 ELSE n+1 FI]bit}
(NOT_B( B_TO_S sum[1][1]) CONC
          CAST{STRING[IF m>=n THEN m ELSE n FI]bit}( (INT j=1..IF m>=n THEN m ELSE n FI] sum[j][2]))
END.


MAC ADD_US_ACTEL = (STRING[INT m]bit:ain,STRING[INT n]bit:bin,bit:cinb) ->STRING[IF m>=n THEN m+1 ELSE n+1 FI]bit:
BEGIN
     MAKE [IF m>=n THEN m ELSE n FI]FA1B:sum.

#unsigned nos so extend by 0#
     LET a_c = IF m>=n THEN ain ELSE ZERO{n-m}b"0" CONC ain FI,
       b_c = IF n>=m THEN bin ELSE  ZERO{m-n}b"0" CONC bin FI.
     LET subsignal = sum.

#lsb#
JOIN   (a_c[IF m>=n THEN m ELSE n FI],b_c[IF m>=n THEN m ELSE n FI],cinb)    ->sum[IF m>=n THEN m ELSE n FI].

FOR INT j=1..(IF m>=n THEN m ELSE n FI) -1
JOIN (a_c[(IF m>=n THEN m ELSE n FI) -j],b_c[(IF m>=n THEN m ELSE n FI) -j],
     sum[(IF m>=n THEN m ELSE n FI) -j+1][1])              ->sum[(IF m>=n THEN m ELSE n FI) -j].

OUTPUT  CAST{STRING[IF m>=n THEN m+1 ELSE n+1 FI]bit}
(NOT_B(B_TO_S sum[1][1]) CONC
          CAST{STRING[IF m>=n THEN m ELSE n FI]bit}([INT j=1..IF m>=n THEN m ELSE n FI] sum[j][2]) )
```

```
END.

MAC ADD_SUB_ST =(STRING[INT m]bit:ain,STRING[INT n]bit:bin,t_add:sel) ->STRING[IF m>=n THEN m+1 ELSE n+1 FI]bit:

BEGIN

#sign extend inputs#
      LET a_s = CAST{STRING[1]bit}ain[1] CONC ain,
          b_s = CAST{STRING[1]bit}bin[1] CONC bin,
          sel_bit = CAST{STRING[1]bit}sel,
#ACTEL#
      bin_inv = XOR_B{n+1}(b_s, ALL_SAME{n+1}sel_bit),

#cinb is active low so cast sel(add->0,sub->1) & invert it#
        out= ADD_S_ACTEL(a_s,bin_inv,CAST{bit}NOT_B sel_bit),
      binout= out[2..IF m>=n THEN m+2 ELSE n+2 FI]

 OUTPUT binout
 END.

 #transformation ops#
 MAC B_TO_S= (bit:in)    ->STRING[1]bit: CASE in
                          OF b'0:b"0",
                            b'1:b"1"
                    ESAC.
 MAC I_TO_SC{INT n} = (t_result: in)     -> (flag,STRING[n]bit): BIOP TRANSFORM_S.
 MAC SC_TO_I{INT n} = (STRING[n]bit:in)   -> (flag,t_result): BIOP TRANSFORM_S.

 MAC S_TO_IN = (STRING[INT n]bit:in) -> (flag,t_input): BIOP TRANSFORM_S.
 MAC IN_TO_S{INT n} = (t_input: in)     -> (flag,STRING[n]bit): BIOP TRANSFORM_S.
```

```
MAC U_TO_IN = (STRING[INT n]bit:in) -> (flag,t_input): BIOP TRANSFORM_US.

MAC U_TO_LEN = (STRING[INT n]bit:in) -> (flag,t_length): BIOP TRANSFORM_US.
MAC LEN_TO_U{INT n} =(t_length:in)  -> (flag,STRING[n]bit): BIOP TRANSFORM_US.

MAC Q_TO_U{INT n} =(t_quant:in)      -> (flag,STRING[n]bit): BIOP TRANSFORM_US.
MAC S_TO_C  = (STRING[INT n]bit:in)     ->(flag,t_col):BIOP TRANSFORM_US.
MAC S_TO_R  = (STRING[INT n]bit:in)     ->(flag,t_row):BIOP TRANSFORM_US.
MAC S_TO_B  = (STRING[INT n]bit:in)     ->(flag,t_blk):BIOP TRANSFORM_US.
MAC S_TO_SUB  = (STRING[INT n]bit:in)     ->(flag,t_sub):BIOP TRANSFORM_US.
MAC S_TO_SPARC  = (STRING[INT n]bit:in)     ->(flag,t_sparc_addr):BIOP TRANSFORM_US.

MAC C_TO_S{INT n} = (t_col: in)     -> (flag,STRING[n]bit): BIOP TRANSFORM_US.
MAC R_TO_S{INT n} = (t_row: in)     -> (flag,STRING[n]bit): BIOP TRANSFORM_US.

MAC I_TO_Q = (t_input:in)    ->t_quant:ARITH in.


MAC B_TO_I= (bit:in)    ->t_result: CASE in
                          OF b'0:result/0,
                            b'1:result/1
                      ESAC.

MAC CARRY= (t_add:in)   ->STRING[1]bit: CASE in
                          OF add:b"0",
                            subt:b"1"
                      ESAC.
MAC BOOL_BIT = (bool:in)       ->STRING[1] bit:
CASE in
OF   t:b"1"
```

```
ELSE b'0'
ESAC.

MAC BOOL_STRING{INT n} = ([n]bool:in)   ->STRING[n] bit:
(LET out = BOOL_BIT in[1].
OUTPUT IF n=1
      THEN out
      ELSE out[1] CONC  BOOL_STRING{n-1}(in[2..n])
      FI
).

MAC BIT_STRING{INT n} = ([n]bit:in)   ->STRING[n] bit:
(LET out = B_TO_S in[1].
OUTPUT IF n=1
      THEN out
      ELSE out[1] CONC  BIT_STRING{n-1}(in[2..n])
      FI
).

MAC ZERO{INT n} = (STRING[1]bit:dummy)  ->STRING[n]bit:
IF n=1 THEN b'0'
ELSE b'0' CONC ZERO{n-1} b'0'
FI.

MAC ALL_SAME{INT n} = (STRING[1]bit:dummy)  ->STRING[n]bit:
IF n=1 THEN dummy
ELSE dummy CONC ALL_SAME{n-1} dummy
FI.
```

COM
The operators described in this section are optimal and take two-valued operands and produce a two-valued result. They may not be used with ELLA-integers or associated types.

The first basic value of any two-valued type declaration of the operand(s) and the result are interpreted by the operations as false, and the second basic value is interpreted as true. Thus, given the following type declarations:

MOC

MAC AND_T = (TYPE t: a b) -> t: BIOP AND.

MAC OR_T = (TYPE t: a b) -> t: BIOP OR.

MAC XOR_T = (TYPE t: a b) -> t: BIOP XOR.

MAC NOT_T = (TYPE t: a) -> t: BIOP NOT.

COM
The following operations take bit-string operand(s) and are bitwise, ie the operation is performed on the operand(s) one bit at a time. The operand(s) and result must all be ELLA-strings of the same length.
MOC

MAC AND_B = (STRING[INT n]bit,STRING[n]bit) -> STRING[n]bit:
BIOP AND.

MAC OR_B = (STRING[INT n]bit,STRING[n]bit) -> STRING[n]bit:
BIOP OR.

```
MAC XOR_B = (STRING[INT n]bit,STRING[n]bit) -> STRING[n]bit:
BIOP XOR.

MAC NOT_B = (STRING[INT n]bit) -> STRING[n]bit:
BIOP NOT.


COM
The operators described in this section may be used with primitive types ie
all enumerated types, except associated types, rows, strings and structures.
These operations take two operands which must be of the same type and the
result can be any two-valued type; we have packaged these BIOPs so they output
a value of type 'bool' - you may change this if you wish.
MOC

MAC EQ = (TYPE t: a b ) -> bool: BIOP EQ.

MAC GT = (TYPE t: a b ) -> bool: BIOP GT.

MAC GE = (TYPE t: a b ) -> bool: BIOP GE.

MAC LT = (TYPE t: a b ) -> bool: BIOP LT.

MAC LE = (TYPE t: a b ) -> bool: BIOP LE.

COM
NOTE: these BIOPs are designed to take any primitive ELLA type.  Since it is
not possible to distinguish between primitive and other types, whilst leaving
the macro declaration general enough to allow the use of all two-valued types
that might be declared,  there are  type-checking limitations.  This is done
at network assembly, so use of illegal types will not generate an error
```

```
message until then.

NB: ARITH provides for relational operations on ELLA-integer types.
MOC

COM
These operations are optimal in their handling of '?' and operate on
bit-string representations of unsigned integers.  The result may be any
two-valued type; we have used type 'bool'.  The inputs can be of different
lengths and different types.
MOC

MAC EQ_U = (STRING[INT n]bit,STRING[INT m]bit) -> bool:
BIOP EQ_US.

MAC GT_U = (STRING[INT n]bit,STRING[INT m]bit) -> bool:
BIOP GT_US.

MAC GE_U = (STRING[INT n]bit,STRING[INT m]bit) -> bool:
BIOP GE_US.

MAC LT_U = (STRING[INT n]bit,STRING[INT m]bit) -> bool:
BIOP LT_US.

MAC LE_U = (STRING[INT n]bit,STRING[INT m]bit) -> bool:
BIOP LE_US.

# Bit-strings representing signed numbers #
COM
These operations are optimal and operate on bit-string representations of
signed integers. The result may be any two-valued type; we have used type
```

'bool'. The inputs can be of different lengths and different types.
MOC

MAC EQ_S = (STRING[INT n]bit,STRING[INT m]bit) -> bool:
BIOP EQ_S.

MAC GT_S = (STRING[INT n]bit,STRING[INT m]bit) -> bool:
BIOP GT_S.

MAC GE_S = (STRING[INT n]bit,STRING[INT m]bit) -> bool:
BIOP GE_S.

MAC LT_S = (STRING[INT n]bit,STRING[INT m]bit) -> bool:
BIOP LT_S.

MAC LE_S = (STRING[INT n]bit,STRING[INT m]bit) -> bool:
BIOP LE_S.

Shift operations
COM
These operate on bit-strings. Both the enclosing macro and the BIOP are parameterised by the number of bits to be shifted (INT p). The macro and BIOP parameters must match. Note that no bits are lost in these shift operations, so you may need to trim the result to achieve the desired effect.

SR means shift right; SL means shift left.

The macros with the suffix '_S' perform arithmetic shifts; those with the

```
suffix '_U' perform bool shifts.
MOC

MAC SL_S{INT p} = (STRING[INT n]bit) -> STRING[n + p]bit:
BIOP SL{p}.

MAC SL_U{INT p} = (STRING[INT n]bit) -> STRING[n + p]bit:
BIOP SL{p}.

MAC SR_S{INT p} = (STRING[INT n]bit) -> STRING[n + p]bit:
BIOP SR_S{p}.

MAC SR_U{INT p} = (STRING[INT n]bit) -> STRING[n + p]bit:
BIOP SR_US{p}.


# Arithmetic operations #

# Bit-strings representing unsigned numbers #

# addition. #

MAC ADD_U = (STRING[INT m]bit,STRING[INT n]bit)
                 -> STRING[IF m >= n THEN m+1 ELSE n+1 FI]bit:
BIOP PLUS_US.

# subtraction on bit-string representations of unsigned integers.  Output is #
# signed. #

MAC SUB_U = (STRING[INT m]bit,STRING[INT n]bit)
                 -> STRING[IF m >= n THEN m+1 ELSE n+1 FI]bit:
```

```
BIOP MINUS_US.

# negation.  Output is signed. #

MAC NEG_U = (STRING[INT n]bit) -> STRING[n+1]bit:
BIOP NEGATE_US.

# multiplication. #

MAC MULT_U = (STRING[INT m]bit,STRING[INT n]bit) -> STRING[m+n]bit:
BIOP TIMES_US.

COM
- divide.  If the divisor is non-zero then the first element of the output is
'ok' and the second and third elements are the quotient and remainder;
otherwise, the first element is 'error' and the rest is set to '?'.
MOC

MAC DIV_U = (STRING[INT m]bit,STRING[INT n]bit)
             -> (flag,STRING[m]bit,STRING[n]bit):
BIOP DIVIDE_US.

# square root. #

MAC SQRT_U = (STRING[INT n]bit) -> STRING[(n+1) % 2]bit:
BIOP SQRT_US.
COM
 modulus (result always positive).  If the divisor is non-zero, then the first
element of the output is 'ok' and the second element is the modulus;
otherwise, the first element is 'error'  and the second is '?'.
```

```
MOC

MAC MOD_U = (STRING[INT m]bit,STRING[INT n]bit)
                -> (flag,STRING[n]bit):
BIOP MOD_US.

COM
- convert between one range of bit-string and another.  If the input value
cannot be represented as a legal value for the output  string, the  result is
'error' and '?'.
MOC

MAC RANGE_U {INT m} = (STRING[INT n]bit)
                -> (flag,STRING[m]bit):
BIOP RANGE_US.

# Bit-strings representing signed numbers #

# addition. #

MAC ADD_S = (STRING[INT m]bit,STRING[INT n]bit)
                -> STRING[IF m >= n THEN m+1 ELSE n+1 FI]bit:
BIOP PLUS_S.

#  subtraction. #

MAC SUB_S = (STRING[INT m]bit,STRING[INT n]bit)
                -> STRING[IF m >= n THEN m+1 ELSE n+1 FI]bit:
BIOP MINUS_S.

# negation. #
```

```
MAC NEG_S = (STRING[INT n]bit) -> STRING[n+1]bit:
BIOP NEGATE_S.

# multiplication. #

MAC MULT_S = (STRING[INT m]bit,STRING[INT n]bit) -> STRING[m+n]bit:
BIOP TIMES_S.

COM
divide.  If the divisor is non-zero then the first element of the output is
'ok 'and the second and third elements are the quotient and remainder;
otherwise, the first element is 'error' and the rest is set to '?'.  The
remainder has the same sign as the divisor.
MOC

MAC DIV_S = (STRING[INT m]bit,STRING[INT n]bit)
            -> (flag,STRING[m]bit,STRING[n]bit):
BIOP DIVIDE_S.

COM
modulus (result always positive).  If the divisor is non-zero, then the first
element of the output is 'ok' and the second element is the unsigned modulus;
otherwise, the first element is 'error' and the second is '?'.
MOC

MAC MOD_S = (STRING[INT m]bit,STRING[INT n]bit)
            -> (flag,STRING[n]bit):
BIOP MOD_S.

COM
```

```
- convert between one range of bit-string and another.  If the input value
cannot be represented as a legal value for the output  string, the result is
'error' and '?'.
MOC

MAC RANGE_S {INT m}= (STRING[INT n]bit)
                  -> (flag,STRING[m]bit):
BIOP RANGE_S.

# absolute value.  The output represents an unsigned integer. #

MAC ABS_S = (STRING[INT n]bit) -> STRING[n]bit:
BIOP ABS_S.


# Built in Register #

MAC DREG{INT interval delay} = (TYPE t) -> t:
ALIEN REGISTER {interval, ?t, 0, delay}.

MAC GEN_DREG{INT interval, CONST (TYPE t): init, INT skew delay} = (t) -> t:
ALIEN REGISTER {interval, init, skew, delay}.


# Built in type conversion #

MAC CAST{TYPE t} = (TYPE s) -> t:
ALIEN CAST.
```

```
MAC ALL_SAME{INT n} = (STRING[1]bit:dummy)  ->STRING[n]bit:
BEGIN
FAULT IF n < 1 THEN "N<1 in ALL_SAME" FI.
OUTPUT IF n=1 THEN dummy
ELSE dummy CONC ALL_SAME{n-1} dummy
FI
END.

MAC CAST {TYPE to} = (TYPE from:in)     ->to:ALIEN CAST.

MAC ZERO{INT n} = (STRING[1]bit:dummy)  ->STRING[n]bit:
BEGIN
FAULT IF n < 1 THEN "N<1 in ZERO" FI.
OUTPUT IF n=1 THEN b"0"
    ELSE b"0" CONC ZERO{n-1} b"0"
    FI
END.

MAC B_TO_S= (bit:in)     ->STRING[1]bit: CASE in
                         OF b'0:b"0",
                           b'1:b"1"
                     ESAC.

MAC S_TO_IN = (STRING[input_exp]bit:in)     -> (flag,t_input): BIOP TRANSFORM_S.
MAC IN_TO_S{INT n} = (t_input: in) -> (flag,STRING[n]bit): BIOP TRANSFORM_S.

MAC S_HUFF = (STRING[6]bit)     ->(flag,t_huffman):BIOP TRANSFORM_US.
MAC HUFF_S = (t_huffman)             ->(flag,STRING[6]bit):BIOP TRANSFORM_US.


MAC BOOL_BIT = (bool:in)   ->STRING[1] bit:
```

```
CASE in
OF  t:b"1"
ELSE b"0"
ESAC.
MAC BIT_BOOL= (bit:in)        ->bool:
CASE in
OF  b'1:t
ELSE f
ESAC.


MAC BOOL_STRING{INT n} = ([n]bool:in)  ->STRING[n] bit:
(LET out = BOOL_BIT in[1].
OUTPUT IF n=1
    THEN out
    ELSE out[1] CONC  BOOL_STRING{n-1}(in[2..n])
    FI
).
# defines the types used for the 2D wavelet chip#

#constant values#
INT    result_exp=14,       #length of result arith#
    input_exp=10,        #length of 1D convolver input/output#
    qmax = 7,          #maximum shift value for quantisation constant#
    result_range = 1 SL (result_exp-1),
    input_range = 1 SL (input_exp-1),
    max_octave=3,  #no of octaves=max_octave +1, can not be less in this example#
    no_octave=max_octave+1,    #"#
    xsize = 10,   #no of bits for ximage#
    ysize = 9,#no of bits for yimage#
    ximage=319,#the xdimension -1 of the image, ie no of cols#
```

```
yimage=239 #the ydimension -1 of the image, ie no of rows#

#int types#
TYPE t_result= NEW result/( -(result_range)..(result_range-1)),
    t_input= NEW input/( -(input_range)..(input_range-1)),
    t_length= NEW len/(0..15),
    t_inp  = NEW inp/(0..1023),
    t_blk   =NEW blk/(0..3),
    t_sub  =NEW sub/(0..3),
    t_col   =NEW col/(0..ximage),
    t_row  =NEW row/(0..yimage),
    t_carry    =NEW carry/(0..1),
    t_quant    =NEW quant/(0..qmax),
 #address for result&dwt memory, ie 1 frame#
    t_sparc_addr  =NEW addr/(0..(1 SL max_octave)*( (ximage+1)*(yimage+1)+(ximage+1))-1 ),
    t_octave=NEW oct/(0..(max_octave+1)),

 #bit string and boolean types types#
    bit = NEW b('0 | '1),
    bool = NEW (f|t),
    flag = NEW(error | ok),

 #control signals#
    t_reset = NEW(rst|no_rst),
    t_load  = NEW(write|read),     #r/wbar  control#
    t_cs =   NEW(no_select|select),  #chip select control#
    t_updown= NEW(down|up),         #up/down counter control#
    t_diff=   NEW(diff|nodiff),   #diff or not in quantiser#
    t_intra = NEW(intra|inter),
```

```
#convolver mux & and types#
    t_mux = NEW(left|right),
    t_mux3 = NEW(l|c|r),
    t_mux4 = NEW(uno|dos|tres|quatro),
    t_add = NEW(add|subt),
    t_direction=NEW(forward|inverse),

#counter types#
    t_count_control=NEW(count_rst|count_carry),
    t_count_2 = NEW(one|two),
#state types#
    t_token = NEW (t_0|t_1|t_11|t_100|t_101),
    t_mode= NEW(void|void_still|stop|send|still|still_send|lpf_send|lpf_still|lpf_stop),
    t_cycle = NEW(token_cycle|data_cycle|skip_cycle),
    t_state= NEW(start|up0|up1|zz0|zz1|zz2|zz3|down1),
    t_decode = NEW(load_low|load_high),
    t_high_low = NEW(low|high),
    t_huffman   = NEW(pass|huffman),
    t_fifo = NEW(ok_fifo|error_fifo),
#types for the octave control unit#
    t_channel= NEW(y|u|v),
    t_channel_factor= NEW(luminance|color),
#types for the control of memory ports#
    t_sparcport=(t_sparc_addr#wr_addr#,t_sparc_addr#rd_addr#,t_load#w/r#,t_cs#cs#)
.
#generate random values for test memories#

FN GEN_RANDOM_MEM = (bool:ck,t_reset:reset) ->t_input: BOOL_INT10 PRBS11(ck,reset).
TYPE t_test = NEW(no|yes).
#..............................................................#
#These functions change types from boolean to inputeger and vice- #
```

```
    FSpOpenDF(&fsspec,fsWrPerm,&fileRefNum);
    area=height*rowBytes;
    FSWrite(fileRefNum,&area,(long*)pixmap);
    FSClose(fileRefNum);*/

    src[0]=(*glob)->src[0]; src[1]=(*glob)->src[1]; src[2]=(*glob)->src[2];
    dst[0]=(*glob)->dst[0]; dst[1]=(*glob)->dst[1]; dst[2]=(*glob)->dst[2];
    switch(kle->seqh.channels) {
    case 3:
        IN32(sGlob->tab[UseF32-1],pixmap,src[0],src[1],src[2],width,height,rowByte
        break;
    }


    /**********************************************
     *
     *  Klics encode
     *
     **********************************************/
#ifdef DEBUG
    if (p->callerFlags&codecFlagUseImageBuffer) DebugStr("\pUseImageBuffer");   /*
    if (p->callerFlags&codecFlagUseScreenBuffer) DebugStr("\pUseScreenBuffer"); /*
    if (p->callerFlags&codecFlagUpdatePrevious) DebugStr("\pUpdatePrevious");    /*
    if (p->callerFlags&codecFlagNoScreenUpdate) DebugStr("\pNoScreenUpdate");    /*
    if (p->callerFlags&codecFlagDontOffscreen) DebugStr("\pDontOffscreen");      /*
    if (p->callerFlags&codecFlagUpdatePreviousComp) DebugStr("\pUpdatePreviousComp
    if (p->callerFlags&codecFlagForceKeyFrame) DebugStr("\pForceKeyFrame");      /*
    if (p->callerFlags&codecFlagOnlyScreenUpdate) DebugStr("\pOnlyScreenUpdate");
#endif

    kle->buf.buf=(unsigned long *)(p->data+sizeof(KlicsFrameHeader));
    kle->encd.intra=(p->temporalQuality==0);
    kle->frmh.frame_number=p->frameNumber;

    bytes=KlicsEncode(src,dst,kle);

    BlockMove((Ptr)&kle->frmh,p->data,sizeof(KlicsFrameHeader));
    bytes+=sizeof(KlicsFrameHeader);

    (*glob)->prev_frame=p->frameNumber;

    p->data+=bytes;
    p->bufferSize=bytes;
    (*p->imageDescription)->dataSize=bytes;

    p->similarity=(kle->encd.intra?0:Long2Fix(244));
    p->callerFlags=0;
/*  p->callerFlags|=codecFlagUsedImageBuffer|(kle->encd.intra?codecFlagUsedNewImag
bail:

    HUnlock((Handle)glob);
#ifdef PERFORMANCE
    if(0!=(result=PerfDump(ThePGlobals,"\pEncode.perf",false,0)))
        return(result);
#endif
    DebugMsg("\pBandCompress success");
    return(result);
}
#endif

/* Display stuff for debugging
    CGrafPtr    wPort, savePort;
```

```
    Rect            rect;
    Str255          str;

    GetPort((GrafPtr *)&savePort);
    GetCWMgrPort(&wPort);
    SetPort((GrafPtr)wPort);
    SetRect(&rect,0,0,50,30);
    ClipRect(&rect);
    EraseRect(&rect);
    NumToString(frmh->frame_number,str);
    MoveTo(0,20);
    DrawString(str);
    if (frmh->flags&KFH_INTRA) {
        SetRect(&rect,0,30,50,65);
        ClipRect(&rect);
        EraseRect(&rect);
        NumToString(frmh->frame_number/24,str);
        MoveTo(0,50);
        DrawString(str);
    }
    SetRect(&rect,-2000,0,2000,2000);
    ClipRect(&rect);
    SetPort((GrafPtr)savePort);*/

#define flag_tree   0x1
#define flag_wave   0x2
#define flag_show   0x4
#define flag_full   0x8
#define DURATION    66666

long    ModeSwitch(Globals *glob,KlicsFrameHeader *frmh)
{
    long    mode=0, i, fps;
    Boolean repeat=glob->prev_frame==frmh->frame_number,
            next=glob->prev_frame+1==frmh->frame_number;
    CGrafPtr    wPort, savePort;
    Rect        rect;
    Str255      str;

    DebugMsg("\pModeSwitch - begin");
    if (frmh->frame_number==0)
        for(i=0;i<15;i++) glob->out[i]=false;
    if (repeat) {
        glob->run_time=0;
        DebugMsg("\pModeSwitch - repeat (end)");
        return(flag_show|flag_full);
    }

    if (next)
        switch(frmh->flags) {
        case KFH_SKIP:
            DebugMsg("\pModeSwitch - next/skip");
            glob->prev_frame=frmh->frame_number;
            if (glob->sys_time>DURATION) {
                glob->run_time=0;
                if (glob->real_frame!=glob->dpy_frame)
                    mode|=flag_wave|flag_show;
            } else {
                unsigned long frame, late;

                frame=glob->run_frame+(glob->sync_time-glob->run_time)/DURATION;
                late=(glob->sync_time-glob->run_time)%DURATION;
                if (frame<=glob->prev_frame && glob->real_frame!=glob->dpy_frame)
```

```
                mode|=flag_wave|flag_show;
/*          if (frame<=glob->prev_frame && late+glob->wave_time+glob->dpy_time
                mode|=flag_wave flag_show;*/
            }
            break;
        case KFH_INTRA:
            DebugMsg("\pModeSwitch - next/intra");
            mode=flag_tree;
            glob->prev_frame=frmh->frame_number;
            glob->real_frame=glob->prev_frame;
            if (glob->sys_time>DURATION) {
                glob->run_time=0;
                mode|=flag_wave|flag_show|flag_full;
            } else
/*              if (glob->run_time==0) {*/
                    glob->key_time=glob->sync_time-glob->run_time;
                    glob->run_time=glob->sync_time-glob->sys_time;
                    glob->run_frame=glob->prev_frame;
                    mode|=flag_wave|flag_show|flag_full;
/*              } else {
                    unsigned long frame, late;

                    frame=glob->run_frame+(glob->sync_time-glob->run_time)/DURATIO
                    late=(glob->sync_time-glob->run_time)%DURATION;
                    if (frame<=glob->prev_frame)
                        mode|=flag_wave|flag_show|flag_full;
                }*/
            break;
        default:
            DebugMsg("\pModeSwitch - next/inter");
            mode=flag_tree;
            glob->prev_frame=frmh->frame_number;
            glob->real_frame=glob->prev_frame;
            if (glob->sys_time>DURATION) {
                glob->run_time=0;
                mode|=flag_wave|flag_show;
            } else
                if (glob->run_time==0) {
                    glob->run_time=glob->sync_time-glob->sys_time;
                    glob->run_frame=glob->prev_frame;
                    mode|=flag_wave|flag_show;
                } else {
                    unsigned long frame, late;

                    frame=glob->run_frame+(glob->sync_time-glob->run_time)/DURATIO
                    late=(glob->sync_time-glob->run_time)%DURATION;
                    if (frame<=glob->prev_frame)
                        mode|=flag_wave|flag_show;
/*                  if (frame<=glob->prev_frame && late+glob->tree_time+glob->wave
                        mode|=flag_wave|flag_show;*/
                }
            break;
        }
    else
        switch(frmh->flags) {
        case KFH_SKIP:
            DebugMsg("\pModeSwitch - jump/skip");
            glob->run_time=0;
            break;
        case KFH_INTRA:
            DebugMsg("\pModeSwitch - jump/intra");
            mode=flag_tree|flag_wave|flag_show|flag_full;
            for(i=glob->prev_frame;i<frmh->frame_number;i++)
```

```
            glob->out[frmh->frame_number%15]=0;
            glob->prev_frame=frmh->frame_number;
            glob->real_frame=glob->prev_frame;
            glob->run_time=0;
            break;
        default:
            DebugMsg("\pModeSwitch - jump/inter");
            glob->run_time=0;
            break;
        }
    DebugMsg("\pModeSwitch - display info");
#ifndef COMPONENT
/*  glob->out[frmh->frame_number%15]=(mode&flag_show)!=0;
    for(i=0,fps=0;i<15;i++) if (glob->out[i]) fps++;
    GetPort((GrafPtr *)&savePort);
    GetCWMgrPort(&wPort);
    SetPort((GrafPtr)wPort);
    SetRect(&rect,0,20,120,50);
    ClipRect(&rect);
    EraseRect(&rect);
    NumToString(frmh->frame_number,str);
    MoveTo(0,35);
    DrawString(str);
    DrawString("\p:");
    NumToString(fps,str);
    DrawString(str);
    MoveTo(0,50);
    for(i=0;i<15;i++)
        if (glob->out[i]) DrawString("\pX");
        else DrawString("\pO");
    SetRect(&rect,-2000,0,2000,2000);
    ClipRect(&rect);
    SetPort((GrafPtr)savePort);*/
#endif
    DebugMsg("\pModeSwitch - end");
    return(mode);
}

#ifndef ENCODER
pascal long
KLBandDecompress(Handle storage,register CodecDecompressParams *p)
{
#pragma unused(storage)
    Globals **glob  = (Globals **)storage;
    ImageDescription    **desc = p->imageDescription;
    int                 x,y;
    char                *baseAddr;
    short               rowBytes;
    Rect                dRect;
    long                offsetH,offsetV;
    OSErr               result = noErr;
    short               *src[3],*dst[3];
    long                *pixmap;
    int                 width=(*desc)->width+KLExtendWidth((*desc)->width);
    int                 height=(*desc)->height+KLExtendHeight((*desc)->height);
    int                 hwidth=width>>1,hheight=height>>1,area=height*width;
    KlicsE              kle;
    KlicsFrameHeader    *frmh;
    char                mmuMode=1;
    long                mode;
    SharedGlobals       *sGlob;
/*
    FILE                *fp;
```

```
    char                    file_name[30];
    CGrafPtr                wPort, savePort;
    Rect                    rect;
    Str255                  str;
*/

    HLock((Handle)glob);
    DebugMsg("\pBandDecompress");
    (*glob)->sys_time=GetTimerValue(&(*glob)->sys_time);
    (*glob)->sys_time-=(*glob)->sync_time;

#ifdef PERFORMANCE
    (void)PerfControl(ThePGlobals,true);
#endif

    kle=&(*glob)->kle;
    sGlob=(*glob)->sharedGlob;

    dRect = p->srcRect;
    if ( !TransformRect(p->matrix,&dRect,nil) ) {
        DebugMsg("\pTransformRect Error");
        return(paramErr);
    }
    rowBytes = p->dstPixMap.rowBytes & 0x3fff;
    offsetH = (dRect.left - p->dstPixMap.bounds.left);
    switch (  p->dstPixMap.pixelSize ) {
    case 32:
        offsetH <<=2;
        break;
    case 16:
        offsetH <<=1;
        break;
    case 8:
        break;
    default:
        result = codecErr;
        DebugMsg("\pDepth Error");
        goto bail;
    }
    offsetV = (dRect.top - p->dstPixMap.bounds.top) * rowBytes;
    baseAddr = p->dstPixMap.baseAddr + offsetH + offsetV;
    pixmap=(long *)baseAddr;

    /*********************************************
     *
     *  Klics decode
     *
     *********************************************/

    src[0]=(*glob)->src[0]; src[1]=(*glob)->src[1]; src[2]=(*glob)->src[2];
    dst[0]=(*glob)->dst[0]; dst[1]=(*glob)->dst[1]; dst[2]=(*glob)->dst[2];

    frmh=(KlicsFrameHeader *)p->data;
    kle->buf.buf=(unsigned long *)(p->data+sizeof(KlicsFrameHeader));
    mode=ModeSwitch(*glob,frmh);

    KlicsDecode(src,dst,&kle->seqh,frmh,&kle->buf,mode,(*glob)->scale,&(*glob)->tr

    if ( kle->buf.ptr-kle->buf.buf > frmh->length+2)
        DebugMsg("\pWarning: Decompressor read passed end of buffer");

    p->data[0]='X';
    p->data[1]=mode&flag_tree?'T':' ';
```

```
	p->data[2]=mode&flag_wave?'W':' ';
	p->data[3]=mode&flag_show?'S':' ';
	p->data[4]=mode&flag_full?'F':' ';
	p->data[5]=frmh->flags&KFH_INTRA?'I':' ';
	p->data[6]=frmh->flags&KFH_SKIP?'K':' ';
	p->data[7]='X';

	p->data+=p->bufferSize;

	/*********************************************
	 *
	 *  signed 10 bit YUV-unsigned 8 RGB convert
	 *
	 *********************************************/

#ifdef COMPONENT
	SwapMMUMode(&mmuMode);
#endif
	if (mode&flag_show) {
		(*glob)->sync_time=GetTimerValue(&(*glob)->sync_time);
		(*glob)->dpy_frame=(*glob)->real_frame;
		if ((*glob)->scale[2]<(*glob)->scale[1]) {
			switch(kle->seqh.channels) {
			case 3:
				switch (p->dstPixMap.pixelSize) {
				case 32:
					if (mode&flag_full)
						OUT32X2(sGlob->tab[Use32-1],pixmap,src[0],src[1],src[2],wi
					else
						OUT32X2D(sGlob->tab[Use32-1],pixmap,src[0],src[1],src[2],w
					break;
				case 16:
					OUT16X2(sGlob->tab[Use16-1],pixmap,src[0],src[1],src[2],width>
					break;
				case 8:
					OUT8X2(sGlob->tab[Use8-1],pixmap,src[0],src[1],src[2],width>>(
					break;
				}
				break;
			}
		} else {
			switch(kle->seqh.channels) {
			case 3:
				switch (p->dstPixMap.pixelSize) {
				case 32:
					if (mode&flag_full)
						OUT32(sGlob->tab[Use32-1],pixmap,src[0],src[1],src[2],widt
					else
						OUT32D(sGlob->tab[Use32-1],pixmap,src[0],src[1],src[2],wid
					break;
				case 16:
					OUT16(sGlob->tab[Use16-1],pixmap,src[0],src[1],src[2],width>>(
					break;
				case 8:
					OUT8(sGlob->tab[Use8-1],pixmap,src[0],src[1],src[2],width>>(*g
					break;
				}
				break;
			}
		}
		(*glob)->dpy_time=GetTimerValue(&(*glob)->dpy_time);
		(*glob)->dpy_time-=(*glob)->sync_time;
	}
```

```
    CLEARA2();
    (*glob)->sync_time=GetTimerValue(&(*glob)->sync_time);

#ifdef COMPONENT
    SwapMMUMode(&mmuMode);
#endif

bail:
    HUnlock((Handle)glob);

#ifdef PERFORMANCE
    if(0!=(result=PerfDump(ThePGlobals,"\pDecode.perf",false,0)))
        return(result);
#endif
    DebugMsg("\pBandDecompress success");
    return(result);
}
#endif
```

Engineering:KlicsCode:CompPict:Klics.h

```
/*******************************
 *
 *  © Copyright 1993 KLICS Limited
 *  All rights reserved.
 *
 *  Written by: Adrian Lewis
 *
 *******************************/
/*
 *  Second generation header file
 */

#include    <stdio.h>

/* useful X definitions */
/*typedef   char    Boolean;*/
typedef char    *String;
#define True    1
#define False   0

/* new Blk definition */
typedef int     Blk[4];

#define WT_Haar  0
#define WT_Daub4 1

/* mode constructors */
#define M_LPF   1
#define M_STILL 2
#define M_SEND  4
#define M_STOP  8
#define M_VOID  16
#define M_QUIT  32

/* LookAhead histogram */
#define HISTO   300
#define HISTO_DELTA 15.0
#define HISTO_BITS 10

/* Fast Functions */

/* Is the block all zero ? */
#define BlkZero(block) \
    block[0]==0 && block[1]==0 && block[2]==0 && block[3]==0

/* Sum of the absolute values */
#define Decide(new) \
    abs(new[0])+ \
    abs(new[1])+ \
    abs(new[2])+ \
    abs(new[3])

/* Sum of the absolute differences */
#define DecideDelta(new,old) \
    abs(new[0]-old[0])+ \
    abs(new[1]-old[1])+ \
    abs(new[2]-old[2])+ \
    abs(new[3]-old[3])

/* Adjust the norm for comparison with SigmaAbs */
#define DecideDouble(norm) (4.0*norm)

/* Get addresses from x,y coords of block, sub-band, octave,
```

```
 * image size and mask (directly related to octave) information
 */
#define GetAddr(addr,x,y,sub,oct,size,mask) \
{ int   smask=mask>>1, \
        x0=x|(sub&1?smask:0), \
        x1=x|(sub&1?smask:0)|mask, \
        y0=(y|(sub&2?smask:0))*size[0], \
        y1=(y|(sub&2?smask:0)|mask)*size[0]; \
 \
    addr[0]=x0+y0; \
    addr[1]=x1+y0; \
    addr[2]=x0+y1; \
    addr[3]=x1+y1; \
}

/* Get data values from addresses and memory */
#define GetData(addr,block,data) \
    block[0]=(int)data[addr[0]]; \
    block[1]=(int)data[addr[1]]; \
    block[2]=(int)data[addr[2]]; \
    block[3]=(int)data[addr[3]];

#define VerifyData(block,mask,tmp) \
    tmp=block&mask; \
    if (tmp!=0 && tmp!=mask) { \
        block=block<0?mask:~mask; \
    }

/* Put data values to memory using addresses */
#define PutData(addr,block,data) \
    data[addr[0]]=(short)block[0]; \
    data[addr[1]]=(short)block[1]; \
    data[addr[2]]=(short)block[2]; \
    data[addr[3]]=(short)block[3];

/* Put zero's to memory using addresses */
#define PutZero(addr,data) \
    data[addr[0]]=0; \
    data[addr[1]]=0; \
    data[addr[2]]=0; \
    data[addr[3]]=0;

/* Mode: M_VOID Put zero's and find new mode */
#define DoZero(addr,dst,mode,oct) \
    PutZero(addr,dst); \
    mode[oct]=oct==0?M_STOP:M_VOID;

/* Descend the tree structure
 * Copy mode, decrement octave (& mask), set branch to zero
 */
#define DownCounters(mode,oct,mask,blk) \
    mode[oct-1]=mode[oct]; \
    oct--; \
    mask = mask>>1; \
    blk[oct]=0;

/* Ascend the tree structure
 * Ascend tree (if possible) until branch not 3
 * If at top then set mode to M_QUIT
 * Else increment branch and x, y coords
 */
#define StopCounters(mode,oct,mask,blk,x,y,octs) \
    while(oct<octs-1 && blk[oct]==3) { \
```

```
        blk[oct]=0; \
        mask= mask<<1; \
        x &= ~mask; \
        y &= ~mask; \
        oct++; \
    } \
    if (oct==octs-1) mode[oct]=M_QUIT; \
    else { \
        blk[oct]++; \
        x ^= mask<<1; \
        if (blk[oct]==2) y ^= mask<<1; \
        mode[oct]=mode[oct+1]; \
    }
```

Engineering:KlicsCode:CompPict:Haar.a

```
*--------------------------------
*
*  © Copyright 1993 KLICS Limited
*  All rights reserved.
*
*  Written by: Adrian Lewis
*
*--------------------------------
*
*  68000 FastForward/Backward Haar
*
*--------------------------------
        macro
        Fwd0        &addr0,&dG,&dH
*
        move.w      (&addr0),&dG     ; dG=*(short *)addr1
        move.w      &dG,&dH          ; dH=dG
*
        endm
*--------------------------------
        macro
        Fwd1        &addr1,&addr0,&dG,&dH
*
        move.w      (&addr1),d0      ; v=*(short *)addr2
        add.w       d0,&dH           ; dH+=v
        sub.w       d0,&dG           ; dG-=v
        clr.w       d0               ; d0=0
        asr.w       #1,&dH           ; dAH>>=1
        addx.w      d0,&dH           ; round dH
        asr.w       #1,&dG           ; dG>>=1
        addx.w      d0,&dG           ; round dG
        move.w      &dH,(&addr0)     ; *(short *)addr0=dH
        move.w      &dG,(&addr1)     ; *(short *)addr1=dG
*
        mend
*--------------------------------
        macro
        Fwd         &base,&end,&inc
*
        movea.l     &base,a0                ; addr0=base
        move.l      &inc,d0                 ; d0=inc
        asr.l       #1,d0                   ; d0=inc>>1
        movea.l     a0,a1                   ; addr1=addr0
        suba.l      d0,a1                   ; addr1-=(inc>>1)
@do     Fwd0        a0,d4,d5                ; Fwd0(addr0,dG,dH)
        adda.l      &inc,a1                 ; addr1+=inc
        Fwd1        a1,a0,d4,d5             ; Fwd1(addr1,addr0,dG,dH)
        adda.l      &inc,a0                 ; addr0+=inc
        cmpa.l      a0,&end                 ; addr0<end
        bgt.s       @do                     ; while
*
        endm
*--------------------------------
HaarForward FUNC    EXPORT
*
        link        a6,#0                   ; no local variables
        movem.l     d4-d7/a3-a5,-(a7)       ; store registers
*
        move.l      $000C(a6),d3            ; inc=inc1
        movea.l     $0008(a6),a5            ; base=data
        move.l      $0010(a6),d6            ; end1
        move.l      $0018(a6),d7            ; end2
        move.l      $0014(a6),d2            ; inc2
```

```
@do     movea.l   a5,a4                  ; end=base
        adda.l    d6,a4                  ; end+=endl
        Fwd       a5,a4,d3               ; Fwd(base,end,inc)
        adda.l    d2,a5                  ; base+=inc2
        cmpa.l    d7,a5                  ; end2>base
        blt.s     @do                    ; for
*
        movem.l   (a7)+,d4-d7/a3-a5      ; restore registers
        unlk      a6                     ; remove locals
        rts                              ; return
*
        ENDFUNC
*-----------------------------------
        macro
        Bwd0      &addr0,&dG,&dH
*
        move.w    (&addr0),&dG     ; dG=*(short *)addr0
        move.w    &dG,&dH          ; dH=dG
*
        endm
*-----------------------------------
        macro
        Bwd1      &addr1,&addr0,&dG,&dH
*
        move.w    (&addr1),d0      ; v=*(short *)addr1
        add.w     d0,&dH           ; dH+=v
        sub.w     d0,&dG           ; dG-=v
        move.w    &dH,(&addr0)     ; *(short *)addr0=dH
        move.w    &dG,(&addr1)     ; *(short *)addr1=dG
*
        endm
*-----------------------------------
        macro
        Bwd       &base,&count,&inc
*
        movea.l   &base,a0               ; addr0=base
        move.l    &inc,d0                ; d0=inc
        asr.l     #1,d0                  ; d0=inc>>1
        movea.l   a0,a1                  ; addr1=addr0
        suba.l    d0,a1                  ; addr1-=(inc>>1)
@do     Bwd0      a0,d4,d5               ; Bwd0(addr0,dG,dH)
        adda.l    &inc,a1                ; addr1+=inc
        Bwd1      a1,a0,d4,d5            ; Bwd1(addr1,addr0,dG,dH)
        adda.l    &inc,a0                ; addr0+=inc
        dbf       &count,@do             ; while -1!=count
*
        endm
*-----------------------------------
HaarBackward    FUNC    EXPORT
*
*   d0 - spare, d1 - count1, d2 - inc2, d3 - inc1, d4 - dG, d5 - dH, d6 - loop1, d
*
        link      a6,#0                  ; no local variables
        movem.l   d4-d7/a3-a5,-(a7)      ; store registers
*
        move.l    $000C(a6),d3           ; inc=inc1
        movea.l   $0008(a6),a5           ; base=data
        move.l    $0010(a6),d6           ; loop1 (width/height)
        move.l    $0018(a6),d7           ; loop2 (height/width)
        move.l    $0014(a6),d2           ; inc2
        subq.l    #1,d7                  ; loop2-=1
        lsr.l     #1,d6                  ; loop1/=2
        subq.l    #1,d6                  ; loop1-=1
```

```
@do     move.l      d6,d1               ; count1=loop1
        Bwd         a5,d1,d3            ; Bwd(base,count,inc)
        adda.l      d2,a5               ; base+=inc2
        dbf         d7,@do              ; while -1!=--loop2
*
        movem.l     (a7)+,d4-d7/a3-a5   ; restore registers
        unlk        a6                  ; remove locals
        rts                             ; return
*
        ENDFUNC
*------------------------------------
HaarXTopBwd FUNC    EXPORT
*
        link        a6,#0               ; no local variables
*
        movea.l     $0008(a6),a0        ; start
        move.l      $000C(a6),d3        ; area
        lsr.l       #1,d3               ; area (long)
        subq.l      #1,d3               ; area-=1
@do     move.l      (a0),d0             ; d0=HG=*Y
        move.l      d0,d1               ; d1=HG
        swap        d1                  ; d1=GH
        neg.w       d0                  ; d0=H(-G)
        add.l       d1,d0               ; d0=01
        move.l      d0,(a0)+            ; *Y++=01
        dbf         d3,@do              ; while -1!=--area
*
        unlk        a6                  ; remove locals
        rts                             ; return
*
        ENDFUNC
*------------------------------------
HaarTopBwd  FUNC    EXPORT
*
        link        a6,#0               ; no local variables
        movem.l     d4-d6,-(a7)         ; store registers
*
        movea.l     $0008(a6),a0        ; startH
        movea.l     a0,a1               ; startG
        move.l      $000C(a6),d4        ; height
        move.l      $0010(a6),d3        ; width
        move.l      d3,d6               ; linelen=width
        add.l       d6,d6               ; linelen (bytes)
        lsr.l       #1,d4               ; height/=2
        lsr.l       #1,d3               ; width/=2
        subq.l      #1,d4               ; height-=1
        subq.l      #1,d3               ; width-=1
@do1    adda.l      d6,a1               ; startG+=linelen
        move.l      d3,d5               ; linecount=width
@do2    move.l      (a0),d0             ; d0=HAHB=*Y0
        move.l      (a1),d1             ; d1=GAGB=*Y1
        move.l      d0,d2               ; d2=HAHB
        add.l       d1,d0               ; d0=0A0B
        sub.l       d1,d2               ; d2=1A1B
*
        move.l      d0,d1               ; d1=HG
        swap        d1                  ; d1=GH
        neg.w       d0                  ; d0=H(-G)
        add.l       d1,d0               ; d0=01
        move.l      d0,(a0)+            ; *Y0++=0A0B
*
        move.l      d2,d1               ; d1=HG
        swap        d1                  ; d1=GH
```

```
        neg.w       d2
        add.l       d1,d2                  ; d2=H(-G)
        move.l      d2,(a1)+               ; d2=01
                                           ; *Y1++=1A1B

        dbf         d5,@do2                ; while -1!=--linecount
        move.l      a1,a0                  ; startH=startG
        dbf         d4,@do1                ; while -1!=--height

        movem.l     (a7)+,d4-d6            ; restore registers
        unlk        a6                     ; remove locals
        rts                                ; return

        ENDFUNC
*---------------------------------
        END
```

Engineering:KlicsCode:CompPict:ConvolveSH3.c

```
/*******************************
 *
 * © Copyright 1993 KLICS Limited
 * All rights reserved.
 *
 * Written by: Adrian Lewis
 *
 *******************************/
/*
    2D wavelet transform convolver (fast hardware emulation)
    New improved wavelet coeffs : 11 19 5 3

    Optimized for speed:
        dirn - False
        src/dst octave == 0
*/

#define FwdS(addr0,dAG,dAH) \
    v=*(short *)addr0; \
    dAG=(v3=v+(vs=v<<1)); \
    dAG+=v+(vs<<=1); \
    dAH=v3+(vs<<=1); \
    dAH+=v3+(vs<<=1);

#define Fwd1(addr1,dAG,dAH,dBG,dBH) \
    v=*(short *)addr1; \
    dBG=(v3=v+(vs=v<<1)); \
    dAH+=v+(vs<<=1); \
    dBH=v3+(vs<<=1); \
    dAG-=v3+(vs<<=1);

#define Fwd2(addr2,addr1,addr0,dAG,dAH,dBG,dBH) \
    v=*(short *)addr2; \
    dAH-=(v3=v+(vs=v<<1)); \
    dBG+=v+(vs<<=1); \
    dAG+=v3+(vs<<=1); \
    dBH+=v3+(vs<<=1); \
    *(short *)addr0=(dAH+15)>>5; \
    *(short *)addr1=(dAG+15)>>5;

#define Fwd3(addr3,dAG,dAH,dBG,dBH) \
    v=*(short *)addr3; \
    dAG=(v3=v+(vs=v<<1)); \
    dBH+=v+(vs<<=1); \
    dAH=v3+(vs<<=1); \
    dBG-=v3+(vs<<=1);

#define Fwd0(addr0,addr3,addr2,dAG,dAH,dBG,dBH) \
    v=*(short *)addr0; \
    dBH-=(v3=v+(vs=v<<1)); \
    dAG+=v+(vs<<=1); \
    dBG+=v3+(vs<<=1); \
    dAH+=v3+(vs<<=1); \
    *(short *)addr2=(dBH+15)>>5; \
    *(short *)addr3=(dBG+15)>>5;

#define FwdE(addr3,addr2,dBG,dBH) \
    v=*(short *)addr3; \
    dBH+=(vs=v<<1); \
    dBG-=(vs<<2); \
    *(short *)addr2=(dBH+15)>>5; \
    *(short *)addr3=(dBG+15)>>5;
```

Engineering:KlicsCode:CompPict:ConvolveSH3.c

```
#define Fwd(base,end,inc) \
    addr0=base; \
    addr3=addr0-(inc>>2); \
    addr2=addr3-(inc>>2); \
    addr1=addr2-(inc>>2); \
    FwdS(addr0,dAG,dAH); \
    addr1+=inc; \
    Fwd1(addr1,dAG,dAH,dBG,dBH); \
    addr2+=inc; \
    Fwd2(addr2,addr1,addr0,dAG,dAH,dBG,dBH); \
    addr3+=inc; \
    while(addr3<end) { \
        Fwd3(addr3,dAG,dAH,dBG,dBH); \
        addr0+=inc; \
        Fwd0(addr0,addr3,addr2,dAG,dAH,dBG,dBH); \
        addr1+=inc; \
        Fwd1(addr1,dAG,dAH,dBG,dBH); \
        addr2+=inc; \
        Fwd2(addr2,addr1,addr0,dAG,dAH,dBG,dBH); \
        addr3+=inc; \
    } \
    FwdE(addr3,addr2,dBG,dBH);

extern  void FASTFORWARD(char *data, long inc1, long end1, long inc2, char *end2);
extern  void HAARFORWARD(char *data, long inc1, long end1, long inc2, char *end2);

void    FastForward(char *data, long inc1, long end1, long inc2, char *end2)
{
    register short  v, vs, v3, dAG, dAH, dBG, dBH, inc;
    register char   *addr0, *addr1, *addr2, *addr3, *end;
    char    *base;

    inc=inc1;
    for(base=data;base<end2;base+=inc2) {
        end=base+end1;
        Fwd(base,end,inc);
    }
}


void    Daub4Forward(short *data, int size[2], int oct_dst)
{
    int     oct, area=size[0]*size[1]<<1;
    short   width=size[0]<<1;
    char    *top=area+(char *)data, *left=width+(char *)data;

    for(oct=0;oct!=oct_dst;oct++) {
        long    cinc=2<<oct, cinc4=cinc<<2,
                rinc=size[0]<<oct+1, rinc4=rinc<<2; /* col and row increments in t

        FASTFORWARD((char *)data,cinc4,width-cinc,rinc,top);
        FASTFORWARD((char *)data,rinc4,area-rinc,cinc,left);
    }
}

void    HaarForward(short *data, int size[2], int oct_dst)
{
    int     oct, area=size[0]*size[1]<<1;
    short   width=size[0]<<1;
    char    *top=area+(char *)data, *left=width+(char *)data;

    for(oct=0;oct!=oct_dst;oct++) {
        long    cinc=2<<oct, cinc2=cinc<<1.
```

Engineering:KlicsCode:CompPict:ConvolveSH3.c

```
            rinc=size[0]<<oct+1, rinc2=rinc<<1; /* col and row increments in t

        HAARFORWARD((char *)data,cinc2,width,rinc,top);
        HAARFORWARD((char *)data,rinc2,area,cinc,left);
    }


void    HybridForward(short *data, int size[2], int oct_dst)
{
    int     oct, area=size[0]*size[1]<<1;
    short   width=size[0]<<1;
    char    *top=area+(char *)data, *left=width+(char *)data;

    HAARFORWARD((char *)data,4,width,size[0]<<1,top);
    HAARFORWARD((char *)data,size[0]<<2,area,2,left);
    for(oct=1;oct!=oct_dst;oct++) {
        long    cinc=2<<oct, cinc4=cinc<<2,
                rinc=size[0]<<oct+1, rinc4=rinc<<2; /* col and row increments in t

        FASTFORWARD((char *)data,cinc4,width-cinc,rinc,top);
        FASTFORWARD((char *)data,rinc4,area-rinc,cinc,left);
    }
}

#define BwdS0(addr0,dAG,dAH,dBH) \
    v=*(short *)addr0; \
    dAG= -(v3=v+(vs=v<<1)); \
    dAH=v+(vs<<=1); \
    dBH=vs<<1; \

#define BwdS1(addr1,addr0,dAG,dAH,dBH) \
    v=*(short *)addr1; \
    dBH+=(vs=v<<1); \
    v3=vs+v; \
    dAG+=v3+(vs<<=2); \
    dAH-=v3+(vs<<=1); \
    *(short *)addr0=(dBH+3)>>3;

#define Bwd2(addr2,dAG,dAH,dBG,dBH) \
    v=*(short *)addr2; \
    dBG= -(v3=v+(vs=v<<1)); \
    dBH=v+(vs<<=1); \
    dAH+=v3+(vs<<=1); \
    dAG+=v3+(vs<<=1);

#define Bwd3(addr3,addr2,addr1,dAG,dAH,dBG,dBH) \
    v=*(short *)addr3; \
    dAH+=(v3=v+(vs=v<<1)); \
    dAG+=v+(vs<<=1); \
    dBG+=v3+(vs<<=1); \
    dBH-=v3+(vs<<=1); \
    *(short *)addr1=(dAH+7)>>4; \
    *(short *)addr2=(dAG+7)>>4;

#define Bwd0(addr0,dAG,dAH,dBG,dBH) \
    v=*(short *)addr0; \
    dAG= -(v3=v+(vs=v<<1)); \
    dAH=v+(vs<<=1); \
    dBH+=v3+(vs<<=1); \
    dBG+=v3+(vs<<=1);

#define Bwd1(addr1,addr0,addr3,dAG,dAH,dBG,dBH) \
    v=*(short *)addr1; \
```

```
    dBH+=(v3=v+(vs=v<<1)); \
    dBG+=v+(vs<<=1); \
    dAG+=v3+(vs<<=1); \
    dAH-=v3+(vs<<=1); \
    *(short *)addr3=(dBH+7)>>4; \
    *(short *)addr0=(dBG+7)>>4;

#define BwdE2(addr2,dAG,dAH,dBH) \
    v=*(short *)addr2; \
    v3=v+(vs=v<<1); \
    dBH=(vs<<=2); \
    dAH+=v3+vs; \
    dAG+=v3+(vs<<=1);

#define BwdE3(addr3,addr2,addr1,dAG,dAH,dBH) \
    v=*(short *)addr3; \
    dAH+=(v3=v+(vs=v<<1)); \
    dAG+=v+(vs<<=1); \
    dBH-=v3+(vs<<=1); \
    dBH-=v3+(vs<<=1); \
    *(short *)addr1=(dAH+7)>>4; \
    *(short *)addr2=(dAG+7)>>4; \
    *(short *)addr3=(dBH+3)>>3;

#define Bwd(base,end,inc) \
    addr0=base; \
    addr3=addr0-(inc>>2); \
    addr2=addr3-(inc>>2); \
    addr1=addr2-(inc>>2); \
    BwdS0(addr0,dAG,dAH,dBH); \
    addr1+=inc; \
    BwdS1(addr1,addr0,dAG,dAH,dBH); \
    addr2+=inc; \
    while(addr2<end) { \
        Bwd2(addr2,dAG,dAH,dBG,dBH); \
        addr3+=inc; \
        Bwd3(addr3,addr2,addr1,dAG,dAH,dBG,dBH); \
        addr0+=inc; \
        Bwd0(addr0,dAG,dAH,dBG,dBH); \
        addr1+=inc; \
        Bwd1(addr1,addr0,addr3,dAG,dAH,dBG,dBH); \
        addr2+=inc; \
    } \
    BwdE2(addr2,dAG,dAH,dBH); \
    addr3+=inc; \
    BwdE3(addr3,addr2,addr1,dAG,dAH,dBH);

extern void FASTBACKWARD(char *data, long inc1, long loop1, long inc2, char *end2)
extern void HAARBACKWARD(char *data, long inc1, long loop1, long inc2, long loop2)
extern void HAARTOPBWD(char *data,long height,long width);
/* extern void  HAARXTOPBWD(char *data,long area);*/

void    FastBackward(char *data, long inc1, long end1, long inc2, char *end2)
{
    register short  v, vs, v3, dAG, dAH, dBG, dBH, inc;
    register char   *addr0, *addr1, *addr2, *addr3, *end;
    char    *base;

    inc=inc1;
    for(base=data;base<end2;base+=inc2) {
        end=base+end1;
        Bwd(base,end,inc);
    }
```

```
}

void    Daub4Backward(short *data,int size[2],int oct_src)
{
    int     oct, area=size[0]*size[1]<<1;
    short   width=size[0]<<1;
    char    *top=area+(char *)data, *left=width+(char *)data;

    for(oct=oct_src-1;oct>=0;oct--) {
        long    cinc=2<<oct, cinc4=cinc<<2,
                rinc=size[0]<<oct+1, rinc4=rinc<<2; /* col and row increments in t

        FASTBACKWARD((char *)data,rinc4,area-(rinc<<1),cinc,left);
        FASTBACKWARD((char *)data,cinc4,width-(cinc<<1),rinc,top);
    }
}

void    HaarBackward(data,size,oct_src)

short   *data;
int     size[2], oct_src;

{
    int     oct, area=size[0]*size[1]<<1;
    short   width=size[0]<<1;
    char    *top=area+(char *)data, *left=width+(char *)data;

    for(oct=oct_src-1;oct>0;oct--) {
        long    cinc=2<<oct, cinc2=cinc<<1,
                rinc=size[0]<<oct+1, rinc2=rinc<<1; /* col and row increments in t

        HAARBACKWARD((char *)data,rinc2,size[1]>>oct,cinc,size[0]>>oct);
        HAARBACKWARD((char *)data,cinc2,size[0]>>oct,rinc,size[1]>>oct);
    }
    HAARTOPBWD((char *)data,size[1],size[0]);
/*  HAARXTOPBWD((char *)data,area>>1);*/
}

void    HybridBackward(data,size,oct_src)

short   *data;
int     size[2], oct_src;

{
    int     oct, area=size[0]*size[1]<<1;
    short   width=size[0]<<1;
    char    *top=area+(char *)data, *left=width+(char *)data;

    for(oct=oct_src-1;oct>0;oct--) {
        long    cinc=2<<oct, cinc4=cinc<<2,
                rinc=size[0]<<oct+1, rinc4=rinc<<2; /* col and row increments in t

        FASTBACKWARD((char *)data,rinc4,area-(rinc<<1),cinc,left);
        FASTBACKWARD((char *)data,cinc4,width-(cinc<<1),rinc,top);
    }
    HAARTOPBWD((char *)data,size[1],size[0]);
/*  HAARXTOPBWD((char *)data,area>>1);*/
}
```

Engineering:KlicsCode:CompPict:ConvolveSH3.a

```
*--------------------------------
*
*   © Copyright 1993 KLICS Limited
*   All rights reserved.
*
*   Written by: Adrian Lewis
*
*--------------------------------
*
*   68000 FastForward/Backward code
*
*--------------------------------
        seg         'klics'

        macro
        FwdStart    &addr0,&dAG,&dAH
*
        move.w      (&addr0),d0      ; v=*(short *)addr0
        move.w      d0,d1            ; vs=v
        add.w       d1,d1            ; vs<<=1
        move.w      d1,d2            ; v3=vs
        add.w       d0,d2            ; v3=vs+v
        move.w      d2,&dAG          ; dAG=v3
        add.w       d1,d1            ; vs<<=1
        add.w       d0,&dAG          ; dAG+=v
        add.w       d1,&dAG          ; dAG+=vs
        move.w      d2,&dAH          ; dAH=v3
        add.w       d1,d1            ; vs<<=1
        add.w       d1,&dAH          ; dAH+=vs
        add.w       d2,&dAH          ; dAH+=v3
        add.w       d1,d1            ; vs<<=1
        add.w       d1,&dAH          ; dAH+=vs
*
        endm
*--------------------------------
        macro
        FwdOdd      &addr1,&dAG,&dAH,&dBG,&dBH
*
        move.w      (&addr1),d0      ; v=*(short *)addr1
        move.w      d0,d1            ; vs=v
        add.w       d1,d1            ; vs<<=1
        move.w      d1,d2            ; v3=vs
        add.w       d0,d2            ; v3=vs+v
        move.w      d2,&dBG          ; dBG=v3
        add.w       d1,d1            ; vs<<=1
        add.w       d0,&dAH          ; dAH+=v
        add.w       d1,&dAH          ; dAH+=vs
        move.w      d2,&dBH          ; dBH=v3
        add.w       d1,d1            ; vs<<=1
        add.w       d1,&dBH          ; dBH+=vs
        sub.w       d2,&dAG          ; dAG-=v3
        add.w       d1,d1            ; vs<<=1
        sub.w       d1,&dAG          ; dAG-=vs
*
        endm
*--------------------------------
        macro
        FwdEven     &addr2,&addr1,&addr0,&dAG,&dAH,&dBG,&dBH
*
        move.w      (&addr2),d0      ; v=*(short *)addr2
        move.w      d0,d1            ; vs=v
        add.w       d1,d1            ; vs<<=1
        move.w      d1,d2            ; v3=vs
```

```
        add.w       d0,d2               ; v3=vs+v
        sub.w       d2,&dAH             ; dAH-=v3
        add.w       d1,d1               ; vs<<=1
        add.w       d0,&dBG             ; dBG+=v
        add.w       d1,&dBG             ; dBG+=vs
        add.w       d2,&dAG             ; dAG+=v3
        add.w       d1,d1               ; vs<<=1
        add.w       d1,&dAG             ; dAG+=vs
        add.w       d2,&dBH             ; dBH+=v3
        add.w       d1,d1               ; vs<<=1
        add.w       d1,&dBH             ; dBH+=vs
        clr.w       d0                  ; d0=0
        asr.w       #5,&dAH             ; dAH>>=5
        addx.w      d0,&dAH             ; round dAH
        asr.w       #5,&dAG             ; dAG>>=5
        addx.w      d0,&dAG             ; round dAG
        move.w      &dAH,(&addr0)       ; *(short *)addr0=dAH
        move.w      &dAG,(&addr1)       ; *(short *)addr1=dAG
*
        mend
*-----------------------------------
        macro
        FwdEnd  &addr3,&addr2,&dBG,&dBH
*
        move.w      (&addr3),d0         ; v=*(short *)addr3
        add.w       d0,d0               ; v<<=1
        add.w       d0,&dBH             ; dBH+=v
        lsl.w       #2,d0               ; v<<=2
        sub.w       d0,&dBG             ; dBG-=v
        clr.w       d0                  ; d0=0
        asr.w       #5,&dBH             ; dBH>>=5
        addx.w      d0,&dBH             ; round dBH
        asr.w       #5,&dBG             ; dBG>>=5
        addx.w      d0,&dBG             ; round dBG
        move.w      &dBH,(&addr2)       ; *(short *)addr2=dBH
        move.w      &dBG,(&addr3)       ; *(short *)addr3=dBG
*
        endm
*-----------------------------------
        macro
        Fwd         &base,&end,&inc
*
        movea.l     &base,a0                    ; addr0=base
        move.l      &inc,d0                     ; d0=inc
        asr.l       #2,d0                       ; d0=inc>>2
        movea.l     a0,a3                       ; addr3=addr0
        suba.l      d0,a3                       ; addr3-=(inc>>2)
        movea.l     a3,a2                       ; addr2=addr3
        suba.l      d0,a2                       ; addr2-=(inc>>2)
        movea.l     a2,a1                       ; addr1=addr2
        suba.l      d0,a1                       ; addr1-=(inc>>2)
        FwdStart    a0,d4,d5                    ; FwdStart(addr0,dAG,dAH)
        adda.l      &inc,a1                     ; addr1+=inc
        FwdOdd      a1,d4,d5,d6,d7              ; FwdOdd(addr1,dAG,dAH,dBG,dBH)
        adda.l      &inc,a2                     ; addr2+=inc
        FwdEven     a2,a1,a0,d4,d5,d6,d7        ; FwdEven(addr2,addr1,addr0,dAG,dAH,dB
        adda.l      &inc,a3                     ; addr3+=inc
@do     FwdOdd      a3,d6,d7,d4,d5              ; FwdOdd(addr3,dBG,dBH,dAG,dAH)
        adda.l      &inc,a0                     ; addr0+=inc
        FwdEven     a0,a3,a2,d6,d7,d4,d5        ; FwdEven(addr0,addr3,addr2,dBG,dBH,dA
        adda.l      &inc,a1                     ; addr1+=inc
        FwdOdd      a1,d4,d5,d6,d7              ; FwdOdd(addr1,dAG,dAH,dBG,dBH)
        adda.l      &inc,a2                     ; addr2+=inc
```

```
        FwdEven    a2,a1,a0,d4,d5,d6,d7       ; FwdEven(addr2,addr1,addr0,dAG,dAH,dB
        adda.l     &inc,a3                    ; addr3+=inc
        cmpa.l     a3,&end                    ; addr3<end
        bgt.w      @do                        ; while
        FwdEnd     a3,a2,d6,d7                ; FwdEnd(addr3,addr2,dBG,dBH)
*
        endm
*--------------------------------
FastForward FUNC   EXPORT
*
        link       a6,#0                      ; no local variables
        movem.l    d4-d7/a3-a5,-(a7)          ; store registers
*
        move.l     $000C(a6),d3               ; inc=incl
        movea.l    $0008(a6),a5               ; base=data
@do     movea.l    a5,a4                      ; end=base
        adda.l     $0010(a6),a4               ; end+=endl
        Fwd        a5,a4,d3                   ; Fwd(base,end,inc)
        adda.l     $0014(a6),a5               ; base+=inc2
        cmpa.l     $0018(a6),a5               ; end2>base
        blt.w      @do                        ; for
*
        movem.l    (a7)+,d4-d7/a3-a5          ; restore registers
        unlk       a6                         ; remove locals
        rts                                   ; return
*
        ENDFUNC
*--------------------------------
        macro
        BwdStart0  &addr0,&dAG,&dAH,&dBH
*
        move.w     (&addr0),d0       ; v=*(short *)addr0
        move.w     d0,d1             ; vs=v
        add.w      d1,d1             ; vs<<=1 (vs=2v)
        add.w      d1,d0             ; v+=vs (v=3v)
        move.w     d0,&dAG           ; dAG=v3
        neg.w      &dAG              ; dAG= -dAG
        move.w     d0,&dAH           ; dAH=v
        add.w      d1,&dAH           ; dAH+=vs
        lsl.w      #2,d1             ; vs<<=2 (vs=8v)
        move.w     d1,&dBH           ; dBH=vs
*
        endm
*--------------------------------
        macro
        BwdStart1  &addr1,&addr0,&dAG,&dAH,&dBH
*
        move.w     (&addr1),d0       ; v=*(short *)addr1
        move.w     d0,d1             ; vs=v
        add.w      d1,d1             ; vs<<=1
        add.w      d1,&dBH           ; dBH+=vs
        add.w      d1,d0             ; v+=vs  (v=3v)
        lsl.l      #2,d1             ; vs<<=2 (vs=8v)
        add.w      d1,d0             ; v+=vs (v=11v)
        add.w      d0,&dAG           ; dAG+=v
        add.w      d1,d0             ; v+=vs (v=19v)
        sub.w      d0,&dAH           ; dAH-=v
        clr.w      d0                ; d0=0
        asr.w      #3,&dBH           ; dBH>>=3
        addx.w     d0,&dBH           ; round dBH
        move.w     &dBH,(&addr0)     ; *(short *)addr0=dBH
*
        endm
```

Engineering:KlicsCode:CompPict:ConvolveSH3.a

```
*---------------------------------
        macro
        BwdEven &addr2,&dAG,&dAH,&dBG,&dBH
*
        move.w      (&addr2),d0      ; v=*(short *)addr2
        move.w      d0,d1            ; vs=v
        add.w       d1,d1            ; vs<<=1 (vs=2v)
        add.w       d1,d0            ; v+=vs  (v=3v)
        move.w      d0,&dBG          ; dBG=v
        neg.w       &dBG             ; dBG= -dBG
        move.w      d0,&dBH          ; dBH=v
        add.w       d1,&dBH          ; dBH+=vs
        lsl.w       #2,d1            ; vs<<=2 (vs=8v)
        add.w       d1,d0            ; v+=vs (v=11v)
        add.w       d0,&dAH          ; dAH+=v
        add.w       d1,d0            ; v+=vs (v=19v)
        add.w       d0,&dAG          ; dAG+=v
*
        endm
*---------------------------------
        macro
        BwdOdd      &addr3,&addr2,&addr1,&dAG,&dAH,&dBG,&dBH
*
        move.w      (&addr3),d0      ; v=*(short *)addr3
        move.w      d0,d1            ; vs=v
        add.w       d1,d1            ; vs<<=1 (vs=2v)
        add.w       d1,d0            ; v+=vs  (v=3v)
        add.w       d0,&dAH          ; dAH+=v
        add.w       d0,&dAG          ; dAG+=v
        add.w       d1,&dAG          ; dAG+=vs
        lsl.w       #2,d1            ; vs<<=2 (vs=8v)
        add.w       d1,d0            ; v+=vs (v=11v)
        add.w       d0,&dBG          ; dBG+=v
        add.w       d1,d0            ; v+=vs (v=19v)
        sub.w       d0,&dBH          ; dBH-=v
*       clr.w       d0               ; d0=0
        asr.w       #4,&dAH          ; dAH>>=4
*       addx.w      d0,&dAH          ; round dAH
        move.w      &dAH,(&addr1)    ; *(short *)addr1=dAH
        asr.w       #4,&dAG          ; dAG>>=4
*       addx.w      d0,&dAG          ; round dAG
        move.w      &dAG,(&addr2)    ; *(short *)addr2=dAG
*
        endm
*---------------------------------
        macro
        BwdEnd2     &addr2,&dAG,&dAH,&dBH
*
        move.w      (&addr2),d0      ; v=*(short *)addr2
        move.w      d0,d1            ; vs=v
        add.w       d1,d1            ; vs<<=1 (vs=2v)
        add.w       d1,d0            ; v+=vs  (v=3v)
        lsl.w       #2,d1            ; vs<<=2 (vs=8v)
        move.w      d1,&dBH          ; dBH=vs
        add.w       d1,d0            ; v+=vs (v=11v)
        add.w       d0,&dAH          ; dAH+=v
        add.w       d1,d0            ; v+=vs (v=19v)
        add.w       d0,&dAG          ; dAG+=v
*
        endm
*---------------------------------
        macro
        BwdEnd3     &addr3,&addr2,&addr1,&dAG,&dAH,&dBH
```

Engineering:KlicsCode:CompPict:ConvolveSH3.a

```
        move.w      (&addr3),d0          ; v=*(short *)addr3
        move.w      d0,d1                ; vs=v
        add.w       d1,d1                ; vs<<=1 (vs=2v)
        add.w       d1,d0                ; v+=vs  (v=3v)
        add.w       d0,&dAH              ; dAH+=v
        add.w       d0,&dAG              ; dAG+=v
        add.w       d1,&dAG              ; dAG+=vs
        add.w       d1,&dBH              ; dBH+=vs
        lsl.l       #4,d1                ; vs<<=4  (v=32v)
        sub.w       d1,&dBH              ; dBH-=vs
        clr.w       d0                   ; d0=0
        asr.w       #4,&dAH              ; dAH>>=4
        addx.w      d0,&dAH              ; round dAH
        move.w      &dAH,(&addr1)        ; *(short *)addr1=dAH
        asr.w       #4,&dAG              ; dAG>>=4
        addx.w      d0,&dAG              ; round dAG
        move.w      &dAG,(&addr2)        ; *(short *)addr2=dAG
        asr.w       #3,&dBH              ; dBH>>=3
        addx.w      d0,&dBH              ; round dBH
        move.w      &dBH,(&addr3)        ; *(short *)addr3=dBH

        endm
*-----------------------------------
        macro
        Bwd         &base,&end,&inc

        movea.l     &base,a0                    ; addr0=base
        move.l      &inc,d0                     ; d0=inc
        asr.l       #2,d0                       ; d0=inc>>2
        movea.l     a0,a3                       ; addr3=addr0
        suba.l      d0,a3                       ; addr3-=(inc>>2)
        movea.l     a3,a2                       ; addr2=addr3
        suba.l      d0,a2                       ; addr2-=(inc>>2)
        movea.l     a2,a1                       ; addr1=addr2
        suba.l      d0,a1                       ; addr1-=(inc>>2)
        BwdStart0   a0,d4,d5,d7                 ; BwdStart0(addr0,dAG,dAH,dBH)
        adda.l      &inc,a1                     ; addr1+=inc
        BwdStart1   a1,a0,d4,d5,d7              ; BwdStart1(addr1,addr0,dAG,dAH,dBH)
        adda.l      &inc,a2                     ; addr2+=inc
@do     BwdEven     a2,d4,d5,d6,d7              ; BwdEven(addr2,dAG,dAH,dBG,dBH)
        adda.l      &inc,a3                     ; addr3+=inc
        BwdOdd      a3,a2,a1,d4,d5,d6,d7        ; BwdOdd(addr3,addr2,addr1,dAG,dAH,dBG
        adda.l      &inc,a0                     ; addr0+=inc
        BwdEven     a0,d6,d7,d4,d5              ; BwdEven(addr0,dBG,dBH,dAG,dAH)
        adda.l      &inc,a1                     ; addr1+=inc
        BwdOdd      a1,a0,a3,d6,d7,d4,d5        ; BwdOdd(addr1,addr0,addr3,dBG,dBH,dAG
        adda.l      &inc,a2                     ; addr2+=inc
        cmpa.l      a2,&end                     ; addr2<end
        bgt         @do                         ; while
        BwdEnd2     a2,d4,d5,d7                 ; BwdEnd2(addr2,dAG,dAH,dBH)
        adda.l      &inc,a3                     ; addr3+=inc
        BwdEnd3     a3,a2,a1,d4,d5,d7           ; BwdEnd3(addr3,addr2,addr1,dAG,dAH,dB

        endm
*-----------------------------------
FastBackward    FUNC     EXPORT
*
        link        a6,#0                       ; no local variables
        movem.l     d4-d7/a3-a5,-(a7)           ; store registers

        move.l      $000C(a6),d3                ; inc=incl
        movea.l     $0008(a6),a5                ; base=data
```

Engineering:KlicsCode:CompPict:ConvolveSH3.a

```
@do     movea.l   a5,a4                   ; end=base
        adda.l    $0010(a6),a4            ; end+=end1
        Bwd       a5,a4,d3                ; Bwd(base,end,inc)
        adda.l    $0014(a6),a5            ; base+=inc2
        cmpa.l    $0018(a6),a5            ; end2>base
        blt.w     @do                     ; for
*
        movem.l   (a7)+,d4-d7/a3-a5       ; restore registers
        unlk      a6                      ; remove locals
        rts                               ; return
*
        ENDFUNC
*------------------------------------
        END
```

Engineering:KlicsCode:CompPict:Colour.c

```
/*******************************
 *
 *  © Copyright 1993 KLICS Limited
 *  All rights reserved.
 *
 *  Written by: Adrian Lewis
 *
 *******************************/
/*
 *  Test versions of colour space conversions in C
 */

#include <Memory.h>
#include <QuickDraw.h>

#define NewPointer(ptr,type,size) \
    saveZone=GetZone(); \
    SetZone(SystemZone()); \
    if (nil==(ptr=(type)NewPtr(size))) { \
        SetZone(ApplicZone()); \
        if (nil==(ptr=(type)NewPtr(size))) { \
            SetZone(saveZone); \
            return(MemoryError()); \
        } \
    } \
    SetZone(saveZone);

typedef union {
    long    pixel;
    char    rgb[4];
} Pixel;

/* Special YUV space version */
#define rgb_yuv(pixmap,Yc) \
    pixel.pixel=0x808080^*pixmap++; \
    r=(short)pixel.rgb[1]; \
    g=(short)pixel.rgb[2]; g+=g; \
    b=(short)pixel.rgb[3]; \
    Y=(b<<3)-b; \
    g+=r; \
    Y+=g+g+g; \
    Y>>=4; \
    Y+=g; \
    *Yc++=Y; \
    Y>>=2; \
    U+=b-Y; \
    V+=r-Y;

#define limit(Y,low,high) \
    Y<(low<<2)?low<<2:Y>(high<<2)?high<<2:Y

/* Standard YUV space version - Bt294 CR07(0) mode limiting */
#define rgb_yuv32(pixmap,Yc) \
    pixel.pixel=0x808080^*pixmap++; \
    r=(long)pixel.rgb[1]; \
    g=(long)pixel.rgb[2]; \
    b=(long)pixel.rgb[3]; \
    Y= (306*r + 601*g + 117*b)>>8; \
    *Yc++ = limit(Y,16-128,235-128); \
    U+= (512*r - 429*g - 83*b)>>8; \
    V+= (-173*r - 339*g + 512*b)>>8;

void    RGB2YUV32(long *pixmap, short *Yc, short *Uc, short *Vc, int area, int wid
```

```
    long    *pixmap2=pixmap+cols, *row, *end=pixmap+area;
    short   *Yc2=Yc+width;

    while(pixmap<end) {
        row=pixmap+width;
        while(pixmap<row) {
            Pixel   pixel;
            long    r,g,b,Y,U=0,V=0;

            rgb_yuv32(pixmap,Yc);
            rgb_yuv32(pixmap,Yc);
            rgb_yuv32(pixmap2,Yc2);
            rgb_yuv32(pixmap2,Yc2);
            U>>=2;
            V>>=2;
            *Uc++=limit(U,16-128,240-128);
            *Vc++=limit(V,16-128,240-128);
        }
        pixmap+=cols+cols-width;
        pixmap2+=cols+cols-width;
        Yc+=width;
        Yc2+=width;
    }
}

typedef struct {
    short   ry, rv, by, bu;
} RGB_Tab;

OSErr RGBTable(long **tab)
{
    RGB_Tab *table;
    int     i;
    THz     saveZone;

    NewPointer(table,RGB_Tab*,256*sizeof(RGB_Tab));
    *tab=(long *)table;
    for(i=0;i<128;i++) {
        table[i].ry=306*i>>8;
        table[i].rv=173*i>>8;
        table[i].by=117*i>>8;
        table[i].bu=83*i>>8;
    }
    for(i=128;i<256;i++) {
        table[i].ry=306*(i-256)>>8;
        table[i].rv=173*(i-256)>>8;
        table[i].by=117*(i-256)>>8;
        table[i].bu=83*(i-256)>>8;
    }
    return(noErr);
}

typedef struct {
    short   ru, gu, bv, gv;
} UV32_Tab;

UV32_Tab *UV32_Table()
{
    UV32_Tab    *table;
    int     i;

    table=(UV32_Tab *)NewPtr(256*sizeof(UV32_Tab));
```

```
    for(i=0;i<128;i++) {
        table[i].ru=128+(1436*i>>10);
        table[i].gu=128+(-731*i>>10);
        table[i].bv=128+(1815*i>>10);
        table[i].gv=-352*i>>10;
    }
    for(i=128;i<256;i++) {
        table[i].ru=128+(1436*(i-256)>>10);
        table[i].gu=128+(-731*(i-256)>>10);
        table[i].bv=128+(1815*(i-256)>>10);
        table[i].gv=-352*(i-256)>>10;
    }
    return(table);
}

typedef struct {
    long    u, v;
} UV32Tab;

OSErr   UV32Table(long **tab)
{
    long    *ytab;
    UV32Tab *uvtab;
    int     i;
    THz     saveZone;

    NewPointer(*tab,long*,512*sizeof(long)+512*sizeof(UV32Tab));
    ytab=*tab;
    uvtab=(UV32Tab*)&ytab[512];
    for(i=-256;i<256;i++) {
        long    yyy, sp;

        sp=0x000000fe&(i<-128?0:i>127?255:i+128);
        yyy=sp; yyy<<=8;
        yyy|=sp; yyy<<=8;
        yyy|=sp;
        ytab[0x000001ff&i]=yyy;
    }
    for(i=-256;i<256;i++) {
        long    ru,gu,bv,gv;

        ru=0xfffffffe & (1436*i>>10);
        gu=0x000001fe & (-731*i>>10);
        bv=0x000001fe & (1815*i>>10);
        gv=0x000001fe & (-352*i>>10);

        uvtab[0x000001FF&i].u=((ru<<8)|gu)<<8;
        uvtab[0x000001FF&i].v=(gv<<8)|bv;
    }
    return(noErr);
}

typedef struct {
    short   u, v;
} UV16Tab;

OSErr   UV16Table(long **tab)
{
    short   *ytab;
    UV16Tab *uvtab;
    int     i;
    THz     saveZone;
```

```
    NewPointer(*tab,long*,512*sizeof(short)-512*sizeof(UV16Tab));
    ytab=*(short **)tab;
    uvtab=(UV16Tab*)&ytab[512];
    for(i=-256;i<256;i++) {
        long    yyy, sp;

        sp=0x0000001e&((i<-128?0:i>127?255:i-128)>>3);
        yyy=sp; yyy<<=5;
        yyy|=sp; yyy<<=5;
        yyy|=sp;
        ytab[0x000001ff&i]=yyy;
    }
    for(i=-256;i<256;i++) {
        long    ru,gu,bv,gv;

        ru=0xfffffffe & (1436*i>>13);
        gu=0x0000003e & (-731*i>>13);
        bv=0x0000003e & (1815*i>>13);
        gv=0x0000003e & (-352*i>>13);

        uvtab[0x000001FF&i].u=((ru<<5)|gu)<<5;
        uvtab[0x000001FF&i].v=(gv<<5)|bv;
    }
    return(noErr);
}

#define over(val) \
    ((0xFF00&(val)) == 0)?(char)val:val<0?0:255

/* Standard YUV space version */
#define yuv_rgb32(pixmap,Yc) \
    Y=(*Yc++)>>2; \
    pixel.rgb[1]=over(Y+r); \
    pixel.rgb[2]=over(Y+g); \
    pixel.rgb[3]=over(Y+b); \
    *pixmap++=pixel.pixel;


void    YUV2RGB32(long *pixmap, short *Yc, short *Uc, short *Vc, int area, int wid
{
    long    *pixmap2=pixmap+cols, *row, *end=pixmap+area;
    short   *Yc2=Yc+width;

    while(pixmap<end) {
        row=pixmap+width;
        while(pixmap<row) {
            Pixel   pixel;
            long    r,g,b,Y,U,V;

            U=(*Uc++)>>2;
            V=(*Vc++)>>2;
            r=128+(1436*U>>10);
            g=128+(-731*U - 352*V>>10);
            b=128+(1815*V>>10);

            yuv_rgb32(pixmap,Yc);
            yuv_rgb32(pixmap,Yc);
            yuv_rgb32(pixmap2,Yc2);
            yuv_rgb32(pixmap2,Yc2);
        }
        pixmap+=cols+cols-width;
        pixmap2+=cols+cols-width;
        Yc+=width;
```

```
        Yc2+=width;
    }
}

#define rgb32_yuv(pixmap,Yc) \
    pixel.pixel=0x808080^*pixmap++; \
    r=pixel.rgb[1]; \
    g=pixel.rgb[2]; \
    b=pixel.rgb[3]; \
    Y= (table[0xFF&r].ry + (g<<2)-table[0xFF&g].ry-table[0xFF&g].by + table[0xFF&b
    *Yc++ = limit(Y,16-128,235-128); \
    U+= (r<<1) -g -table[0xFF&g].rv - table[0xFF&b].bu; \
    V+= (b<<1) -g -table[0xFF&r].rv - table[0xFF&g].bu;

void    RGB32YUV(RGB_Tab *table,long *pixmap, short *Yc, short *Uc, short *Vc, int
{
    long    *pixmap2=pixmap+cols, *row, *end=pixmap+area;
    short   *Yc2=Yc+width;

    while(pixmap<end) {
        row=pixmap+width;
        while(pixmap<row) {
            Pixel   pixel;
            long    r,g,b,Y,U=0,V=0;

/*          rgb32_yuv(pixmap,Yc);*/
            pixel.pixel=0x808080^*pixmap++;
            r=pixel.rgb[1];
            g=pixel.rgb[2];
            b=pixel.rgb[3];
            Y= (table[0xFF&r].ry + (g<<2)-table[0xFF&g].ry-table[0xFF&g].by + tabl
            *Yc++ = limit(Y,16-128,235-128);
            U+= (r<<1) -g -table[0xFF&g].rv - table[0xFF&b].bu;
            V+= (b<<1) -g -table[0xFF&r].rv - table[0xFF&g].bu;

            rgb32_yuv(pixmap,Yc);
            rgb32_yuv(pixmap2,Yc2);
            rgb32_yuv(pixmap2,Yc2);
            U>>=2;
            V>>=2;
            *Uc++=limit(U,16-128,240-128);
            *Vc++=limit(V,16-128,240-128);
        }
        pixmap+=cols+cols-width;
        pixmap2+=cols+cols-width;
        Yc+=width;
        Yc2+=width;
    }
}

#define yuv_rgb32x2(pixmap,Y) \
    pixel.rgb[1]=over(Y+r); \
    pixel.rgb[2]=over(Y+g); \
    pixel.rgb[3]=over(Y+b); \
    pixmap[cols]=pixel.pixel; \
    *pixmap++=pixel.pixel;

void    YUV2RGB32x2(UV32_Tab *table,long *pixmap, short *Yc, short *Uc, short *Vc,
{
    long    *pixmap2=pixmap+2*cols, *row, *end=pixmap+area;
    short   *Yc2=Yc+width;
```

```
    while(pixmap<end) {
        long    Yold=*Yc>>2, Yold2=*Yc2>>2;

        row=pixmap+width*2;
        while(pixmap<row) {
            Pixel   pixel;
            long    r,g,b,Y,U,V;

            U=0x00FF&((*Uc++)>>2);
            V=0x00FF&((*Vc++)>>2);
            r=table[U].ru;
            g=table[U].gu+table[V].gv;
            b=table[V].bv;

            Y=(*Yc++)>>2;
            Yold=(Y+Yold)>>1;
            yuv_rgb32x2(pixmap,Yold);

            Yold=Y;
            yuv_rgb32x2(pixmap,Yold);

            Y=(*Yc++)>>2;
            Yold=(Y+Yold)>>1;
            yuv_rgb32x2(pixmap,Yold);

            Yold=Y;
            yuv_rgb32x2(pixmap,Yold);

            Y=(*Yc2++)>>2;
            Yold2=(Y+Yold2)>>1;
            yuv_rgb32x2(pixmap2,Yold2);

            Yold2=Y;
            yuv_rgb32x2(pixmap2,Yold2);

            Y=(*Yc2++)>>2;
            Yold2=(Y+Yold2)>>1;
            yuv_rgb32x2(pixmap2,Yold2);

            Yold2=Y;
            yuv_rgb32x2(pixmap2,Yold2);
        }
        pixmap+=4*cols-2*width;
        pixmap2+=4*cols-2*width;
        Yc+=width;
        Yc2+=width;
    }
}

#define yuv_rgb8(pixel,Yc,index,dith) \
    Y=*Yc++; \
    Y<<=3; \
    Y&= 0x3F00; \
    Y|= U; \
    pixel.rgb[index]=table[Y].rgb[dith];

void    YUV2RGB8(Pixel *table,long *pixmap, short *Yc, short *Uc, short *Vc, int a
{
    long    *pixmap2=pixmap+cols/1, *row, *end=pixmap+area/4;
    short   *Yc2=Yc+width;

    while(pixmap<end) {
```

```
        row=pixmap+width/4;
        while(pixmap<row) {
            Pixel   pixel, pixel2;
            long    Y,U,V;

            U=*Uc++;
            V=*Vc++;
            U>>=2;
            V>>=6;
            U= (U&0xF0) | (V&0x0F);

            yuv_rgb8(pixel,Yc,0,3);
            yuv_rgb8(pixel,Yc,1,0);
            yuv_rgb8(pixel2,Yc2,0,1);
            yuv_rgb8(pixel2,Yc2,1,2);

            U=*Uc++;
            V=*Vc++;
            U>>=2;
            V>>=6;
            U= (U&0xF0) | (V&0x0F);

            yuv_rgb8(pixel,Yc,2,3);
            yuv_rgb8(pixel,Yc,3,0);
            yuv_rgb8(pixel2,Yc2,2,1);
            yuv_rgb8(pixel2,Yc2,3,2);

            *pixmap++=pixel.pixel;
            *pixmap2++=pixel2.pixel;
        }
        pixmap+=(cols+cols-width)/4;
        pixmap2+=(cols+cols-width)/4;
        Yc+=width;
        Yc2+=width;
    }
}

#define yuv_rgb8x2(pixel,pixel2,Y,index,dith,dith2) \
    Y&= 0x3F00; \
    Y|= U; \
    pixel.rgb[index]=table[Y].rgb[dith]; \
    pixel2.rgb[index]=table[Y].rgb[dith2];

void    YUV2RGB8x2(Pixel *table,long *pixmap, short *Yc, short *Uc, short *Vc, int
{
    long    *pixmap2=pixmap+cols/2, *row, *end=pixmap+area/4;
    short   *Yc2=Yc+width;

    while(pixmap<end) {
        long    Yold=*Yc<<3, Yold2=*Yc2<<3;

        row=pixmap+width/2;
        while(pixmap<row) {
            Pixel   pixel, pixel2, pixel3, pixel4;
            long    Y,U,V;

            U=*Uc++;
            V=*Vc++;
            U>>=2;
            V>>=6;
            U= (U&0x00F0) | (V&0x000F);

            Y=(*Yc++)<<3;
```

```
            Yold=(Y+Yold)>>1;
            yuv_rgb8x2(pixel,pixel2,Y,0,3,1);

            Yold=Y;
            yuv_rgb8x2(pixel,pixel2,Y,1,0,2);
            Yold=Y;

            Y=(*Yc++)<<3;
            Yold=(Y+Yold)>>1;
            yuv_rgb8x2(pixel,pixel2,Y,2,3,1);

            Yold=Y;
            yuv_rgb8x2(pixel,pixel2,Y,3,0,2);
            Yold=Y;

            Y=(*Yc2++)<<3;
            Yold2=(Y+Yold2)>>1;
            yuv_rgb8x2(pixel3,pixel4,Y,0,3,1);

            Yold2=Y;
            yuv_rgb8x2(pixel3,pixel4,Y,1,0,2);
            Yold2=Y;

            Y=(*Yc2++)<<3;
            Yold2=(Y+Yold2)>>1;
            yuv_rgb8x2(pixel3,pixel4,Y,2,3,1);

            Yold2=Y;
            yuv_rgb8x2(pixel3,pixel4,Y,3,0,2);
            Yold2=Y;

            pixmap[cols/4]=pixel2.pixel;
            *pixmap++=pixel.pixel;

            pixmap2[cols/4]=pixel4.pixel;
            *pixmap2++=pixel3.pixel;
        }
        pixmap+=(cols+cols-width)/2;
        pixmap2+=(cols+cols-width)/2;
        Yc+=width;
        Yc2+=width;
    }
}

#define yuv_rgbTEST(pixel,index,Y) \
    rgb_col.red=(Y+r<<8); \
    rgb_col.green=(Y+g<<8); \
    rgb_col.blue=(Y+b<<8); \
    pixel.rgb[index]=Color2Index(&rgb_col);


void    YUV2RGBTEST(UV32_Tab *table,long *pixmap, short *Yc, short *Uc, short *Vc,
{
    long    *pixmap2=pixmap+cols/2, *row, *end=pixmap+area/4;
    short   *Yc2=Yc+width;

    while(pixmap<end) {
        long    Yold=*Yc<<3, Yold2=*Yc2<<3;

        row=pixmap+width/2;
        while(pixmap<row) {
            RGBColor    rgb_col;
            Pixel   pixel, pixel2;
```

Engineering:KlicsCode:CompPict:Colour.c

```
            long    r,g,b,Y,U,V;

            U=0x00FF&((*Uc++)>>2);
            V=0x00FF&((*Vc++)>>2);
            r=table[U].ru;
            g=table[U].gu+table[V].gv;
            b=table[V].bv;

            Y=(*Yc++)>>2;
            Yold=(Y+Yold)>>1;
            rgb_col.red=(Yold+r<<8);
            rgb_col.green=(Yold+g<<8);
            rgb_col.blue=(Yold+b<<8);
            pixel.rgb[0]=Color2Index(&rgb_col);

            Yold=Y;
            yuv_rgbTEST(pixel,1,Yold);

            Y=(*Yc++)>>2;
            Yold=(Y+Yold)>>1;
            yuv_rgbTEST(pixel,2,Yold);

            Yold=Y;
            yuv_rgbTEST(pixel,3,Yold);

            Y=(*Yc2++)>>2;
            Yold2=(Y+Yold2)>>1;
            yuv_rgbTEST(pixel2,0,Yold2);

            Yold2=Y;
            yuv_rgbTEST(pixel2,1,Yold2);

            Y=(*Yc2++)>>2;
            Yold2=(Y+Yold2)>>1;
            yuv_rgbTEST(pixel2,2,Yold2);

            Yold2=Y;
            yuv_rgbTEST(pixel2,3,Yold2);

            pixmap[cols/4]=pixel.pixel;
            *pixmap++=pixel.pixel;

            pixmap2[cols/4]=pixel2.pixel;
            *pixmap2++=pixel2.pixel;
        }
        pixmap+=(cols+cols-width)/2;
        pixmap2+=(cols+cols-width)/2;
        Yc+=width;
        Yc2+=width;
    }
}
```

Engineering:KlicsCode:CompPict:Colour.a

```
*--------------------------------
*
*   © Copyright 1993 KLICS Limited
*   All rights reserved.
*
*   Written by: Adrian Lewis
*
*--------------------------------
*
*   68030 Colour space conversions
*
*--------------------------------
        machine mc68030
        seg     'klics'
        include 'Traps.a'
*--------------------------------
        macro
        DPY32x2         &ARGB, &row, &o0, &o1, &n0, &n1
*
        add.l           &n0,&o0                 ;
        lsr.l           #1,&o0                  ; interpolate first pixel
        add.l           &n1,&o1                 ;
        lsr.l           #1,&o1                  ; interpolate first pixel

        move.l          &o0,(&ARGB)
        add.l           &row,&ARGB
        move.l          &o0,(&ARGB)
        add.l           &row,&ARGB
        move.l          &o1,(&ARGB)
        add.l           &row,&ARGB
        move.l          &o1,(&ARGB)+

        move.l          &n1,(&ARGB)
        sub.l           &row,&ARGB
        move.l          &n1,(&ARGB)
        sub.l           &row,&ARGB
        move.l          &n0,(&ARGB)
        sub.l           &row,&ARGB
        move.l          &n0,(&ARGB)+
*
        endm
*--------------------------------
        macro
        DPY32           &ARGB, &row, &o0, &o1, &n0, &n1
*
        move.l          &o0,(&ARGB)
        add.l           &row,&ARGB
        move.l          &o1,(&ARGB)+

        move.l          &n1,(&ARGB)
        sub.l           &row,&ARGB
        move.l          &n0,(&ARGB)+
*
        endm
*--------------------------------
        macro
        UV2RGB32        &AU,&AV,&TAB
*
        add.l           #2048,&TAB              ; move to uvtab

        move.w          &AU,d1                  ; Load U
        lsr.w           #2,d1
        and.w           #$01FF,d1
```

Engineering:KlicsCode:CompPict:Colour.a

```
        move.l      (&TAB,d1.w*8),d0        ; UV now rg (u)

        move.w      &AV,d1                  ; Load V
        lsr.w       #2,d1
        and.w       #$01FF,d1
        add.l       4(&TAB,d1.w*8),d0       ; UV now rgb

        move.l      d0,d1                   ; 3 copies
        move.l      d0,d2
        move.l      d0,d3

        sub.l       #2048,&TAB              ; restore ytab
*
        endm
*-----------------------------------
        macro
        GETY32      &AY, &TAB, &RGB0, &RGB1
*
        move.l      &AY,d4                  ;Y
        lsr.w       #2,d4
        and.w       #$01FF,d4
        add.l       (&TAB,d4.w*4),&RGB1     ; RGB1+=YYY

        swap        d4
        lsr.w       #2,d4
        and.w       #$01FF,d4
        add.l       (&TAB,d4.w*4),&RGB0     ; RGB0+=YYY
*
        endm
*-----------------------------------
        macro
        OVER32      &RGB
*
        move.l      &RGB,d4             ; copy pixel
        andi.l      #$01010100,d4       ; was it this rgb
        beq.s       @nx_rgb             ; if not then quit
        btst        #24,d4              ; R overflow?
        beq.s       @bit16              ; if not then continue
        btst        #23,&RGB            ; test sign
        beq.s       @pos23              ; if positive
        andi.l      #$0000ffff,&RGB     ; underflow sets R to 0
        bra.s       @bit16              ; do next bit
@pos23  ori.l       #$00ff0000,&RGB     ; overflow sets R to 255
@bit16  btst        #16,d4              ; G overflow?
        beq.s       @bit8               ; if not then continue
        btst        #15,&RGB            ; test sign
        beq.s       @pos16              ; if positive
        andi.w      #$00ff,&RGB         ; underflow sets G to 0
        bra.s       @bit8               ; do next bit
@pos16  ori.w       #$ff00,&RGB         ; overflow sets G to 255
@bit8   btst        #8,d4               ; B overflow?
        beq.s       @end                ; if not then continue
        btst        #7,&RGB             ; test sign
        seq         &RGB                ; under/over flow
@end    andi.l      #$00fefefe,&RGB     ; mask RGB ok
@nx_rgb
*
        endm
*-----------------------------------
        macro
        HASHOUT32   &AH, &D0, &D1, &D2, &D3
*
        move.l      &D0,d4
```

```
        add.l       &D1,d4
        add.l       &D2,d4
        add.l       &D3,d4
        andi.l      #$03e3e3e0,d4
        move.l      d4,&AH
*
        endm
*-------------------------------
        macro
        HASHCMP32   &AH, &D0, &D1, &D2, &D3
*
        move.l      &D0,d4
        add.l       &D1,d4
        add.l       &D2,d4
        add.l       &D3,d4
        andi.l      #$03e3e3e0,d4
        cmp.l       &AH,d4
*
        endm
*-------------------------------
OUT32X2 FUNC    EXPORT
*
PS      RECORD      8
table   DS.L        1
pixmap  DS.L        1
Y       DS.L        1
U       DS.L        1
V       DS.L        1
width   DS.L        1
height  DS.L        1
rowByte DS.L        1
pixmap2 DS.L        1
        ENDR
*
LS      RECORD      0,DECR
Y1      DS.L        1           ; sizeof(short)*Yrow            = 2*width
U_ex    DS.L        1           ; x end address                 = U+U_ix
U_ey    DS.L        1           ; y end address                 = U+width*height>>
U_ix    DS.L        1           ; sizeof(short)*UVrow           = width
Y_y     DS.L        1           ; sizeof(short)*Yrow            = 2*width
P_y     DS.L        1           ; 4*rowBytes-sizeof(long)*Prow  = 4*rowBytes-width
LSize   EQU         *
        ENDR
*
*       a0 - Y, a1 - U, a2 - V, a3 - pixmap, a4 - table, a5 - pixmap2
*       d0 - rgb00, d1 - rgb01, d2 - rgb10, d3 - rgb11, d4 - spare, d6 - old0, d7
*
        link        a6,#LS.LSize            ; inc, width, fend and rowend are loca
        movem.l     d4-d7/a3-a5,-(a7)       ; store registers
*
        move        SR,d0

        move.l      PS.Y(a6),a0             ; Y=Yc
        move.l      PS.U(a6),a1             ; U=Uc
        move.l      PS.V(a6),a2             ; V=Vc
        move.l      PS.pixmap(a6),a3        ; pm=pixmap
        move.l      PS.table(a6),a4         ; tab=table
        move.l      PS.pixmap2(a6),a5       ; pm2=pixmap2

        move.l      PS.width(a6),d0         ; LOAD width
        move.l      d0,LS.U_ix(a6)          ; SAVE U_ix
        move.l      PS.height(a6),d1        ; LOAD height
        mulu.w      d0,d1                   ;  width*height
```

Engineering:KlicsCode:CompPict:Colour.a

```
        lsr.l       #1,d1                   ;  width*height/2
        add.l       a1,d1                   ;  U+width*height/2
        move.l      d1,LS.U_ey(a6)          ; SAVE U_ey
        add.l       d0,d0                   ;  width*2
        move.l      d0,LS.Y1(a6)            ; SAVE Y1
        move.l      d0,LS.Y_y(a6)           ; SAVE Y_y
        lsl.l       #2,d0                   ;  width*8
        move.l      PS.rowByte(a6),d1       ; LOAD rowBytes
        lsl.l       #2,d1                   ;  rowBytes*4
        sub.l       d0,d1                   ;  rowBytes*4-width*8
        move.l      d1,LS.P_y(a6)           ; SAVE P_y

        move.l      PS.rowByte(a6),d5       ; load rowBytes
        clr.l       d6                      ; clear old2
        clr.l       d7                      ; clear old1

@do_y   move.l      LS.U_ix(a6),d0          ; LOAD U_ixB
        add.l       a1,d0                   ;  P+U_ixB
        move.l      d0,LS.U_ex(a6)          ; SAVE U_exB

@do_x   UV2RGB32    (a1)+,(a2)+,a4          ; uv2rgb(*U++,*V++)

        move.l      LS.Y1(a6),d4            ; load Yrow
        GETY32      (a0,d4.l),a4,d2,d3      ; add Yb to RGB values
        GETY32      (a0)+,a4,d0,d1          ; add Ya to RGB values

        move.l      d0,d4
        or.l        d1,d4
        or.l        d2,d4
        or.l        d3,d4
        andi.l      #$01010100,d4
        bne.s       @over                   ; if overflow

@ok     HASHOUT32   (a5)+,d0,d1,d2,d3

        DPY32x2     a3,d5,d6,d7,d0,d2
        DPY32x2     a3,d5,d0,d2,d1,d3

        move.l      d1,d6                   ; copy olds
        move.l      d3,d7

        cmpa.l      LS.U_ex(a6),a1
        blt.w       @do_x

        add.l       LS.Y_y(a6),a0
        add.l       LS.P_y(a6),a3

        cmpa.l      LS.U_ey(a6),a1
        blt.w       @do_y

        movem.l     (a7)+,d4-d7/a3-a5       ; restore registers
        unlk        a6                      ; remove locals
        rts                                 ; return
@over   OVER32      d0
        OVER32      d1
        OVER32      d2
        OVER32      d3
        bra         @ok
*
        ENDFUNC
*---------------------------------
OUT32X2D    FUNC    EXPORT
*
```

Engineering:KlicsCode:CompPict:Colour.a

```
PS       RECORD      8
table    DS.L        1
pixmap   DS.L        1
Y        DS.L        1
U        DS.L        1
V        DS.L        1
width    DS.L        1
height   DS.L        1
rowByte  DS.L        1
pixmap2  DS.L        1
         ENDR
*
LS       RECORD      0,DECR
Y1       DS.L        1          ; sizeof(short)*Yrow              = 2*width
U_ex     DS.L        1          ; x end address                   = U+U_ix
U_ey     DS.L        1          ; y end address                   = U+width*height>>
U_ix     DS.L        1          ; sizeof(short)*UVrow             = width
Y_y      DS.L        1          ; sizeof(short)*Yrow              = 2*width
P_y      DS.L        1          ; 4*rowBytes-sizeof(long)*Prow    = 4*rowBytes-width
LSize    EQU         *
         ENDR
*
*        a0 - Y, a1 - U, a2 - V, a3 - pixmap, a4 - table, a5 - pixmap2
*        d0 - rgb00, d1 - rgb01, d2 - rgb10, d3 - rgb11, d4 - spare, d6 - old0, d7
*
         link        a6,#LS.LSize            ; inc, width, fend and rowend are loca
         movem.l     d4-d7/a3-a5,-(a7)       ; store registers
*
         move.l      PS.Y(a6),a0             ; Y=Yc
         move.l      PS.U(a6),a1             ; U=Uc
         move.l      PS.V(a6),a2             ; V=Vc
         move.l      PS.pixmap(a6),a3        ; pm=pixmap
         move.l      PS.table(a6),a4         ; tab=table
         move.l      PS.pixmap2(a6),a5       ; pm2=pixmap2

         move.l      PS.width(a6),d0         ; LOAD width
         move.l      d0,LS.U_ix(a6)          ; SAVE U_ix
         move.l      PS.height(a6),d1        ; LOAD height
         mulu.w      d0,d1                   ;  width*height
         lsr.l       #1,d1                   ;  width*height/2
         add.l       a1,d1                   ;  U+width*height/2
         move.l      d1,LS.U_ey(a6)          ; SAVE U_ey
         add.l       d0,d0                   ;  width*2
         move.l      d0,LS.Y1(a6)            ; SAVE Y1
         move.l      d0,LS.Y_y(a6)           ; SAVE Y_y
         lsl.l       #2,d0                   ;  width*8
         move.l      PS.rowByte(a6),d1       ; LOAD rowBytes
         lsl.l       #2,d1                   ;  rowBytes*4
         sub.l       d0,d1                   ;  rowBytes*4-width*8
         move.l      d1,LS.P_y(a6)           ; SAVE P_y

         move.l      PS.rowByte(a6),d5       ; load rowBytes
         clr.l       d6                      ; clear old2
         clr.l       d7                      ; clear old1

@do_y    move.l      LS.U_ix(a6),d0          ; LOAD U_ixB
         add.l       a1,d0                   ;  P+U_ixB
         move.l      d0,LS.U_ex(a6)          ; SAVE U_exB

@do_x    UV2RGB32    (a1)+,(a2)+,a4          ; uv2rgb(*U++,*V++)

         move.l      LS.Y1(a6),d4            ; load Yrow
         GETY32      (a0,d4.l),a4,d2,d3      ; add Yb to RGB values
```

```
        GETY32      (a0)+,a4,d0,d1          ; add Ya to RGB values

        move.l      d0,d4
        or.l        d1,d4
        or.l        d2,d4
        or.l        d3,d4
        andi.l      #$01010100,d4
        bne.w       @over                   ; if overflow

@ok     HASHCMP32   (a5)+,d0,d1,d2,d3
        bne.s       @diff

        add.l       #16,a3                  ; add four pixels

@cont   move.l      d1,d6                   ; copy olds
        move.l      d3,d7

        cmpa.l      LS.U_ex(a6),a1
        blt.w       @do_x

        add.l       LS.Y_y(a6),a0
        add.l       LS.P_y(a6),a3

        cmpa.l      LS.U_ey(a6),a1
        blt.w       @do_y
*
        movem.l     (a7)+,d4-d7/a3-a5       ; restore registers
        unlk        a6                      ; remove locals
        rts                                 ; return
@diff   move.l      d4,-4(a5)
        DPY32x2     a3,d5,d6,d7,d0,d2
        DPY32x2     a3,d5,d0,d2,d1,d3
        bra.s       @cont
@over   OVER32      d0
        OVER32      d1
        OVER32      d2
        OVER32      d3
        bra         @ok
*
        ENDFUNC
*---------------------------------
OUT32   FUNC    EXPORT
*
PS      RECORD      8
table   DS.L        1
pixmap  DS.L        1
Y       DS.L        1
U       DS.L        1
V       DS.L        1
width   DS.L        1
height  DS.L        1
rowByte DS.L        1
pixmap2 DS.L        1
        ENDR
*
LS      RECORD      0,DECR
Y1      DS.L        1       ; sizeof(short)*Yrow              = 2*width
U_ex    DS.L        1       ; x end address                   = U+U_ix
U_ey    DS.L        1       ; y end address                   = U+width*height>>
U_ix    DS.L        1       ; sizeof(short)*UVrow             = width
Y_y     DS.L        1       ; sizeof(short)*Yrow              = 2*width
P_y     DS.L        1       ; 2*rowBytes-sizeof(long)*Prow    = 2*rowBytes-width
LSize   EQU         *
```

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```
        ENDR

;       a0 - Y, a1 - U, a2 - V, a3 - pixmap, a4 - table, a5 - pixmap2
;       d0 - rgb00, d1 - rgb01, d2 - rgb10, d3 - rgb11, d4 - spare, d6 - old0, d7

        link        a6,#LS.LSize            ; inc, width, fend and rowend are loca
        movem.l     d4-d7/a3-a5,-(a7)       ; store registers

        move.l      PS.Y(a6),a0             ; Y=Yc
        move.l      PS.U(a6),a1             ; U=Uc
        move.l      PS.V(a6),a2             ; V=Vc
        move.l      PS.pixmap(a6),a3        ; pm=pixmap
        move.l      PS.table(a6),a4         ; tab=table
        move.l      PS.pixmap2(a6),a5       ; pm2=pixmap2

        move.l      PS.width(a6),d0         ; LOAD width
        move.l      d0,LS.U_ix(a6)          ; SAVE U_ix
        move.l      PS.height(a6),d1        ; LOAD height
        mulu.w      d0,d1                   ;  width*height
        lsr.l       #1,d1                   ;  width*height/2
        add.l       a1,d1                   ;  U+width*height/2
        move.l      d1,LS.U_ey(a6)          ; SAVE U_ey
        add.l       d0,d0                   ;  width*2
        move.l      d0,LS.Y1(a6)            ; SAVE Y1
        move.l      d0,LS.Y_y(a6)           ; SAVE Y_y
        add.l       d0,d0                   ;  width*4
        move.l      PS.rowByte(a6),d1       ; LOAD rowBytes
        add.l       d1,d1                   ;  rowBytes*2
        sub.l       d0,d1                   ;  rowBytes*2-width*4
        move.l      d1,LS.P_y(a6)           ; SAVE P_y

        move.l      PS.rowByte(a6),d5       ; load rowBytes
        move.l      LS.Y1(a6),d6            ; load Yrow

@do_y   move.l      LS.U_ix(a6),d7          ; LOAD U_ixB
        add.l       a1,d7                   ;  P+U_ixB

@do_x   UV2RGB32    (a1)+,(a2)+,a4          ; uv2rgb(*U++,*V++)

        GETY32      (a0,d6.l),a4,d2,d3      ; add Yb to RGB values
        GETY32      (a0)+,a4,d0,d1          ; add Ya to RGB values

        move.l      d0,d4
        or.l        d1,d4
        or.l        d2,d4
        or.l        d3,d4
        andi.l      #$01010100,d4
        bne.s       @over                   ; if overflow

@ok     HASHOUT32   (a5)+,d0,d1,d2,d3

        DPY32       a3,d5,d0,d2,d1,d3

        cmpa.l      d7,a1
        blt.w       @do_x

        add.l       LS.Y_y(a6),a0
        add.l       LS.P_y(a6),a3

        cmpa.l      LS.U_ey(a6),a1
        blt.w       @do_y

        movem.l     (a7)+,d4-d7/a3-a5       ; restore registers
```

```
        unlk        a6
        rts                                 ; remove locals
@over   OVER32      d0                      ; return
        OVER32      d1
        OVER32      d2
        OVER32      d3
        bra         @ok
*
        ENDFUNC
*-----------------------------------
OUT32D  FUNC        EXPORT
*
PS      RECORD      8
table   DS.L        1
pixmap  DS.L        1
Y       DS.L        1
U       DS.L        1
V       DS.L        1
width   DS.L        1
height  DS.L        1
rowByte DS.L        1
pixmap2 DS.L        1
        ENDR
*
LS      RECORD      0,DECR
Y1      DS.L        1
U_ex    DS.L        1           ; sizeof(short)*Yrow                = 2*width
U_ey    DS.L        1           ; x end address                     = U+U_ix
U_ix    DS.L        1           ; y end address                     = U+width*height>>
Y_y     DS.L        1           ; sizeof(short)*UVrow               = width
P_y     DS.L        1           ; sizeof(short)*Yrow                = 2*width
LSize   EQU         *           ; 2*rowBytes-sizeof(long)*Prow      = 2*rowBytes-width
        ENDR
*
*       a0 - Y, a1 - U, a2 - V, a3 - pixmap, a4 - table, a5 - pixmap2
*       d0 - rgb00, d1 - rgb01, d2 - rgb10, d3 - rgb11, d4 - spare, d6 - Yrow, d7
*
        link        a6,#LS.LSize            ; inc, width, fend and rowend are loca
        movem.l     d4-d7/a3-a5,-(a7)       ; store registers
*
        move.l      PS.Y(a6),a0             ; Y=Yc
        move.l      PS.U(a6),a1             ; U=Uc
        move.l      PS.V(a6),a2             ; V=Vc
        move.l      PS.pixmap(a6),a3        ; pm=pixmap
        move.l      PS.table(a6),a4         ; tab=table
        move.l      PS.pixmap2(a6),a5       ; pm2=pixmap2

        move.l      PS.width(a6),d0         ; LOAD width
        move.l      d0,LS.U_ix(a6)          ; SAVE U_ix
        move.l      PS.height(a6),d1        ; LOAD height
        mulu.w      d0,d1                   ;  width*height
        lsr.l       #1,d1                   ;  width*height/2
        add.l       a1,d1                   ;  U+width*height/2
        move.l      d1,LS.U_ey(a6)          ; SAVE U_ey
        add.l       d0,d0                   ;  width*2
        move.l      d0,LS.Y1(a6)            ; SAVE Y1
        move.l      d0,LS.Y_y(a6)           ; SAVE Y_y
        add.l       d0,d0                   ;  width*4
        move.l      PS.rowByte(a6),d1       ; LOAD rowBytes
        add.l       d1,d1                   ;  rowBytes*2
        sub.l       d0,d1                   ;  rowBytes*2-width*4
        move.l      d1,LS.P_y(a6)           ; SAVE P_y
```

```
        move.l      PS.rowByte(a6),d5        ; load rowBytes
        move.l      LS.Y1(a6),d6             ; load Yrow

@do_y   move.l      LS.U_ix(a6),d7           ; LOAD U_ixB
        add.l       a1,d7                    ;  P+U_ixB

@do_x   UV2RGB32    (a1)+,(a2)+,a4           ; uv2rgb(*U++,*V++)

        move.l      LS.Y1(a6),d4             ; load Yrow
        GETY32      (a0,d6.l),a4,d2,d3       ; add Yb to RGB values
        GETY32      (a0)+,a4,d0,d1           ; add Ya to RGB values

        move.l      d0,d4
        or.l        d1,d4
        or.l        d2,d4
        or.l        d3,d4
        andi.l      #$01010100,d4
        bne.s       @over                    ; if overflow

@ok     HASHCMP32   (a5)+,d0,d1,d2,d3
        bne.s       @diff

        addq        #8,a3                    ; add four pixels

@cont   cmpa.l      d7,a1
        blt.w       @do_x

        add.l       LS.Y_y(a6),a0
        add.l       LS.P_y(a6),a3

        cmpa.l      LS.U_ey(a6),a1
        blt.w       @do_y
*
        movem.l     (a7)+,d4-d7/a3-a5        ; restore registers
        unlk        a6                       ; remove locals
        rts                                  ; return
@diff   move.l      d4,-4(a5)
        DPY32       a3,d5,d0,d2,d1,d3
        bra.s       @cont
@over   OVER32      d0
        OVER32      d1
        OVER32      d2
        OVER32      d3
        bra         @ok
*
        ENDFUNC
*-----------------------------------
        macro
        UVOV        &VAL, &OV
*
        move.w      &VAL,&OV
        add.w       #$0200,&OV
        and.w       #$FC00,&OV
        beq.s       @ok
        tst.w       &OV
        bge.s       @pos
        move.w      #$01FF,&VAL
        bra.s       @ok
@pos    move.w      #$FE00,&VAL
@ok
*
        endm
```

Engineering:KlicsCode:CompPict:Colour.a

```
UVLIMIT FUNC        EXPORT
* fix d0, d4, spare d1 d2
        UVOV        d0,d1
        swap        d0
        UVOV        d0,d1
        swap        d0
        UVOV        d4,d1
        swap        d4
        UVOV        d4,d1
        swap        d4
        rts

        ENDFUNC

        macro
        UVOVER      &U, &V

        move.l      #$02000200,d1
        move.l      d1,d2
        add.l       &U,d1
        add.l       &V,d2
        or.l        d2,d1
        andi.l      #$FC00FC00,d1
        beq.s       @UVok
        bsr         UVLIMIT
@UVok

        endm

        macro
        GETUV       &AU, &AV, &SP, &UV

        move.l      (&AU)+,&SP
        move.l      (&AV)+,&UV
        UVOVER      &SP,&UV
        lsr.l       #5,&UV
        andi.l      #$03e003e0,&SP
        andi.l      #$001F001F,&UV
        or.l        &SP,&UV                     ; UV==$00UV00UV
        swap        &UV

        endm

        macro
        GETY        &AY,&IND,&UV,&R0,&R1

        move.l      &AY,&R1                     ; (2+) Y=Y0Y1
        lsl.l       #5,&R1                      ; (4) Y=Y0XXY1XX
        andi.l      #$FC00FC00,&R1              ;
        or.w        &UV,&R1                     ; (2) Y=Y1UV
        move.l      (&IND,&R1 .w*4),&R0         ; (2+) R0=0123 (Y1)
        swap        &R1                         ; (4) Y=Y0XX
        or.w        &UV,&R1                     ; (2) Y=Y0UV
        move.l      (&IND,&R1 .w*4),&R1         ; (2+) R1=0123 (Y0)

        endm

        macro
        UV8         &AU, &AV, &SP, &UV

        move.l      (&AU)+,&SP
        move.l      (&AV)+,&UV
        UVOVER      &SP,&UV
```

Engineering:KlicsCode:CompPict:Colour.a

```
        move.l      d0,LS.U_ix(a6)              ; SAVE U_ix
        move.l      PS.height(a6),d1            ; LOAD height
        mulu.w      d0,d1                       ;  width*height
        lsr.l       #1,d1                       ;  width*height/2
        add.l       a1,d1                       ;  U+width*height/2
        move.l      d1,LS.U_ey(a6)              ; SAVE U_ey
        move.l      PS.rowByte(a6),d1           ; LOAD rowBytes
        add.l       d1,d1                       ;  rowBytes*2
        sub.l       d0,d1                       ;  rowBytes*2-width
        move.l      d1,LS.P_y(a6)               ; SAVE P_y
        add.l       d0,d0                       ;  width*2
        move.l      d0,LS.Y1(a6)                ; SAVE Y1
        move.l      d0,LS.Y_y(a6)               ; SAVE Y_y

        move.l      PS.rowByte(a6),d5           ; load rowBytes
        move.l      LS.Y1(a6),d6                ; load Yrow

@do_y   move.l      LS.U_ix(a6),d7              ; LOAD U_ixB
        add.l       a1,d7                       ;  P+U_ixB

@do_x   GETUV       a1,a2,d0,d4

        GETY        (a0,d6.w),a4,d4,d2,d3       ; d2=X0XX. d3=XX1X
        GETY        (a0)+,a4,d4.d0,d1           ; d0=XXX0, d1=1XXX

        move.w      d3,d2                       ; d2=X01X
        lsl.l       #8,d2                       ; d2=01XX
        move.w      d0,d1                       ; d1=1XX0
        swap        d1                          ; d1=X01X
        lsl.l       #8,d1                       ; d1=01XX

        swap        d4                          ; next UV

        GETY        (a0,d6.l),a4,d4,d0,d3       ; d0=X2XX, d3=XX3X
        move.w      d3,d0                       ; d0=X23X
        lsr.l       #8,d0                       ; d0=XX23
        move.w      d0,d2                       ; d2=0123
        GETY        (a0)+,a4,d4,d0,d3           ; d0=XXX2, d3=3XXX
        move.w      d0,d3                       ; d3=3XX2
        swap        d3                          ; d3=X23X
        lsr.l       #8,d3                       ; d3=XX23
        move.w      d3,d1                       ; d1=0123

        move.l      d2,(a3,d5)
        move.l      d1,(a3)+

        cmpa.l      d7,a1
        blt.w       @do_x

        add.l       LS.Y_y(a6),a0
        add.l       LS.P_y(a6),a3

        cmpa.l      LS.U_ey(a6),a1
        blt.w       @do_y
*
        movem.l     (a7)+,d4-d7/a3-a5           ; restore registers
        unlk        a6                          ; remove locals
        rts         ; return
*
        ENDFUNC
*---------------------------------
        macro
        Y8x2        &AY,&IND,&UV,&old
```

```
move.l    &AY,d0                ; (2+) Y=Y0Y1
lsl.l     #3,d0                 ; (4) Y=Y0XXY1XX
swap      d0                    ; (4) Y=Y1XXY0XX
add.w     d0,&old               ; (2) old=old+Y0
lsr.w     #1,&old               ; (4) old=(old+Y0)/2
move.b    &UV,&old              ; (2) old=YI0UV
andi.w    #$3FFF,&old           ; (4) old=0YUV(I0)
move.l    (&IND,&old .w*4),d1   ; (2+) d1=X1X3
move.w    d0,&old               ; (2) old=Y0
move.b    &UV,d0                ; (2) Y=Y0UV
andi.w    #$3FFF,d0             ; (4) Y=0YUV(0)
move.l    (&IND,d0.w*4),d2      ; (2+) d2=0X2X
move.w    d1,d3                 ; (2) exg.w d1,d2
move.w    d2,d1                 ; (2) d1=X12X
move.w    d3,d2                 ; (2) d2=0XX3
swap      d2                    ; (4) d2=X30X
lsl.l     #8,d1                 ; (4) d1=12XX
lsl.l     #8,d2                 ; (4) d2=30XX
swap      d0                    ; (4) Y=Y1XX
add.w     d0,&old               ; (2) old=old+Y1
lsr.w     #1,&old               ; (4) old=(old+Y1)/2
move.b    &UV,&old              ; (2) old=YI1UV
andi.w    #$3FFF,&old           ; (4) old=0YUV(I1)
move.l    (&IND,&old .w*4),d3   ; (2+) d3=X1X3
move.w    d0,&old               ; (2) old=Y1
move.b    &UV,d0                ; (2) Y=Y0UV
andi.w    #$3FFF,d0             ; (4) Y=0YUV(0)
move.l    (&IND,d0.w*4),d0      ; (2+) d0=0X2X
move.w    d0,d1                 ; (2) exg.w d0,d3
move.w    d3,d0                 ; (2) d0=0XX3
move.w    d1,d3                 ; (2) d3=X12X
swap      d0                    ; (4) d0=X30X
lsr.l     #8,d0                 ; (4) d0=XX30
lsr.l     #8,d3                 ; (4) d3=X12X
move.w    d0,d2                 ; (2) d2=3030 (YiY0YiY1) (1)
move.w    d3,d1                 ; (2) d1=2121 (YiY0YiY1) (2)

endm
macro
Y8x2a     &AY,&IND,&UV

GETY      &AY,&IND,&UV,d1,d2
move.l    &AY,d2                ; (2+) Y=Y0Y1
lsl.l     #3,d2                 ; (4) Y=Y0XXY1XX
move.b    &UV,d2                ; (2) Y=Y1UV
andi.w    #$3FFF,d2             ; (4) Y=0YUV(Y1)
move.l    (&IND,d2.w*4),d1      ; (2+) d1=0123 (Y1)
swap      d2                    ; (4) Y=Y0XX
move.b    &UV,d2                ; (2) Y=Y0UV
andi.w    #$3FFF,d2             ; (4) Y=0YUV(Y0)
move.l    (&IND,d2.w*4),d2      ; (2+) d2=0123 (Y0)
move.w    d1,d0                 ; (2) exg.w d2,d1
move.w    d2,d1                 ; (2) d1=0123 (Y1Y0)
move.w    d0,d2                 ; (2) d2=0123 (Y0Y1)
swap      d1                    ; (4) d1=2301 (Y0Y1)

endm

macro
Y8x2b     &AY,&IND,&UV

GETY      &AY,&IND,&UV,d1,d2
```

```
*        move.l      &AY,d2                         ; (2+) Y=Y0Y1
*        lsl.l       #3,d2                          ; (4) Y=Y0XXY1XX
*        move.b      &UV,d2                         ; (2) Y=Y1UV
*        andi.w      #$3FFF,d2                      ; (4) Y=0YUV(Y1)
*        move.l      (&IND,d2.w*4),d1               ; (2+) d1=0123 (Y1)
*        swap        d2                             ; (4) Y=Y0XX
*        move.b      &UV,d2                         ; (2) Y=Y0UV
*        andi.w      #$3FFF,d2                      ; (4) Y=0YUV(Y0)
*        move.l      (&IND,d2.w*4),d2               ; (2+) d2=0123 (Y0)
         ror.l       #8,d2                          ; (6) d2=3012 (Y0)
         ror.l       #8,d1                          ; (6) d1=3012 (Y1)
         move.w      d1,d0                          ; (2) exg.w d2,d1
         move.w      d2,d1                          ; (2) d1=3012 (Y1Y0)
         move.w      d0,d2                          ; (2) d2=3012 (Y0Y1)
         swap        d1                             ; (4) d1=1230 (Y0Y1)
         ror.w       #8,d1                          ; (6) d1=1203 (Y0Y1)
*
         endm


OUT8x2   FUNC     EXPORT
*
PS       RECORD      8
table    DS.L        1
pixmap   DS.L        1
Y        DS.L        1
U        DS.L        1
V        DS.L        1
width    DS.L        1
height   DS.L        1
rowByte  DS.L        1
pixmap2  DS.L        1
         ENDR
*
LS       RECORD      0,DECR
Y1       DS.L        1        ; sizeof(short)*Yrow                 = 2*width
U_ex     DS.L        1        ; x end address                      = U+U_ix
U_ey     DS.L        1        ; y end address                      = U+width*height>>
U_ix     DS.L        1        ; sizeof(short)*UVrow                = width
Y_y      DS.L        1        ; sizeof(short)*Yrow                 = 2*width
P_y      DS.L        1        ; 4*rowBytes-sizeof(long)*Prow       = 4*rowBytes-width
LSize    EQU         *
         ENDR
*
*        a0 - Y, a1 - U, a2 - V, a3 - pixmap, a4 - table, a5 - pixmap2
*        d0 - rgb00, d1 - rgb01, d2 - rgb10, d3 - rgb11, d4 - spare, d5 - old0, d7
*
         link        a6,#LS.LSize             ; inc, width, fend and rowend are loca
         movem.l     d4-d7/a3-a5,-(a7)        ; store registers
*
         move.l      PS.Y(a6),a0              ; Y=Yc
         move.l      PS.U(a6),a1              ; U=Uc
         move.l      PS.V(a6),a2              ; V=Vc
         move.l      PS.pixmap(a6),a3         ; pm=pixmap
         move.l      PS.table(a6),a4          ; tab=table
         adda.l      #$00020000,a4            ; tab+=32768 (longs)
         move.l      PS.pixmap2(a6),a5        ; pm2=pixmap2

         move.l      PS.width(a6),d0          ; LOAD width
         move.l      d0,LS.U_ix(a6)           ; SAVE U_ix
         move.l      PS.height(a6),d1         ; LOAD height
         mulu.w      d0,d1                    ;  width*height
         lsr.l       #1,d1                    ;  width*height/2
```

```
        add.l       a1,d1                   ; U+width*height/2
        move.l      d1,LS.U_ey(a6)          ; SAVE U_ey
        add.l       d0,d0                   ;  width*2
        move.l      d0,LS.Y1(a6)            ; SAVE Y1
        move.l      d0,LS.Y_y(a6)           ; SAVE Y_y
        move.l      PS.rowByte(a6),d1       ; LOAD rowBytes
        add.l       d1,d1                   ;  rowBytes*2
        add.l       d1,d1                   ;  rowBytes*4
        sub.l       d0,d1                   ;  rowBytes*4-width*2
        move.l      d1,LS.P_y(a6)           ; SAVE P_y

        move.l      PS.rowByte(a6),d5       ; load rowBytes
        clr.l       d6
        clr.l       d7

@do_y   move.l      LS.U_ix(a6),d0          ; LOAD U_ixB
        add.l       a1,d0                   ;  P+U_ixB
        move.l      d0,LS.U_ex(a6)          ; SAVE U_exB

@do_x   GETUV       a1,a2,d0,d4             ; d4=00UV00UV (10)

        Y8x2a       (a0),a4,d4;,d6          ; calc d2,d1 pixels
        move.l      d2,(a3)
        add.l       d5,a3
        move.l      d1,(a3)
        add.l       d5,a3

        move.l      LS.Y1(a6),d0            ; load Yrow
        Y8x2b       (a0,d0.w),a4,d4;,d7     ; calc d2,d1 pixels
        move.l      d2,(a3)
        add.l       d5,a3
        move.l      d1,(a3)+

        swap        d4                      ; next UV
        addq.l      #4,a0                   ; next Ys

        move.l      LS.Y1(a6),d0            ; load Yrow
        Y8x2b       (a0,d0.w),a4,d4;,d7     ; calc d2,d1 pixels
        move.l      d1,(a3)
        sub.l       d5,a3
        move.l      d2,(a3)
        sub.l       d5,a3

        Y8x2a       (a0)+,a4,d4;,d6
        move.l      d1,(a3)
        sub.l       d5,a3
        move.l      d2,(a3)+

        cmpa.l      LS.U_ex(a6),a1
        blt.w       @do_x

        add.l       LS.Y_y(a6),a0
        add.l       LS.P_y(a6),a3

        cmpa.l      LS.U_ey(a6),a1
        blt.w       @do_y

        movem.l     (a7)+,d4-d7/a3-a5       ; restore registers
        unlk        a6                      ; remove locals
        rts         ; return

        ENDFUNC
*-------------------------------
```

Engineering:KlicsCode:CompPict:Colour.a

```
        macro
        RGB2Y           &RGB,&Y,&U,&V,&AY
*
        move.l          &RGB,d2                 ; pixel=*pixmap
        eori.l          #$808080,d2             ; pixel^=0x808080
        clr.w           d1                      ; B=0
        move.b          d2,d1                   ; B=pixel[3]
        move.l          4(a4,d1.w*8),d0         ; d0=by,bu
        sub.w           d0,&U                   ; U-=bu
        swap            d0                      ; d0=bu,by
        move.w          d0,&Y                   ; Y=by
        ext.w           d1                      ; (short)B
        add.w           d1,d1                   ; B*=2
        add.w           d1,&V                   ; V+=B<<1
        lsr.l           #8,d2                   ; pixel>>=8
        clr.w           d1                      ; G=0
        move.b          d2,d1                   ; G=pixel[3]
        move.l          (a4,d1.w*8),d0          ; d0=gry,gv
        sub.w           d0,&U                   ; U-=gv
        swap            d0                      ; d0=gv,gry
        sub.w           d0,&Y                   ; Y-=gry
        move.l          4(a4,d1.w*8),d0         ; d0=gby,gu
        sub.w           d0,&V                   ; V-=gv
        swap            d0                      ; d0=gu,gby
        sub.w           d0,&Y                   ; Y-=gby
        ext.w           d1                      ; (short)G
        sub.w           d1,&U                   ; U-=g
        sub.w           d1,&V                   ; V-=g
        lsl.w           #2,d1                   ; G<<=2
        add.w           d1,&Y                   ; Y+=B<<1
        lsr.l           #8,d2                   ; pixel>>=8
        move.l          (a4,d2.w*8),d0          ; d0=ry,rv
        sub.w           d0,&V                   ; V-=rv
        swap            d0                      ; d0=rv,ry
        add.w           d0,&Y                   ; Y+=ry
        ext.w           d2                      ; (short)R
        add.w           d2,d2                   ; R*=2
        add.w           d2,&U                   ; U+=R<<2
        cmpi.w          #$FE40,&Y               ; Y>=-448
        bge.s           @ok                     ; if greater
        move.w          #$FE40,&Y               ; Y= -448
        bra.s           @end                    ; save
@ok     cmpi.w          #$01C0,&Y               ; Y< 448
        blt.s           @end                    ; if less
        move.w          #$01C0,&Y               ; Y= 448
@end    move.w          &Y,&AY                  ; Save Y
*
        endm

IN32    FUNC    EXPORT
*
PS      RECORD          8
table   DS.L            1
pixmap  DS.L            1
Y       DS.L            1
U       DS.L            1
V       DS.L            1
width   DS.L            1
height  DS.L            1
rowByte DS.L            1
        ENDR
*
LS      RECORD          0,DECR
```

```
Y1      DS.L      1          ; sizeof(short)*Yrow             = 2*width
U_ex    DS.L      1          ; x end address                  = U+U_ix
U_ey    DS.L      1          ; y end address                  = U+width*height>>
U_ix    DS.L      1          ; sizeof(short)*UVrow            = width
Y_y     DS.L      1          ; sizeof(short)*Yrow             = 2*width
P_y     DS.L      1          ; 2*rowBytes-sizeof(long)*Prow   = 2*rowBytes-width
LSize   EQU       *
        ENDR
*
*       a0 - Y, a1 - U, a2 - V, a3 - pixmap, a4 - table, a5 - pixmap2
*       d0 - rgb00, d1 - rgb01, d2 - rgb10, d3 - rgb11, d4 - spare, d6 - old0, d7
*
        link      a6,#LS.LSize           ; inc, width, fend and rowend are loca
        movem.l   d4-d7/a3-a5,-(a7)      ; store registers
*
        move.l    PS.Y(a6),a0            ; Y=Yc
        move.l    PS.U(a6),a1            ; U=Uc
        move.l    PS.V(a6),a2            ; V=Vc
        move.l    PS.pixmap(a6),a3       ; pm=pixmap
        move.l    PS.table(a6),a4        ; tab=table

        move.l    PS.width(a6),d0        ; LOAD width
        move.l    d0,LS.U_ix(a6)         ; SAVE U_ix
        move.l    PS.height(a6),d1       ; LOAD height
        mulu.w    d0,d1                  ;  width*height
        lsr.l     #1,d1                  ;  width*height/2
        add.l     a1,d1                  ;  U+width*height/2
        move.l    d1,LS.U_ey(a6)         ; SAVE U_ey
        add.l     d0,d0                  ;  width*2
        move.l    d0,LS.Y1(a6)           ; SAVE Y1
        move.l    d0,LS.Y_y(a6)          ; SAVE Y_y
        add.l     d0,d0                  ;  width*4
        move.l    PS.rowByte(a6),d1      ; LOAD rowBytes
        add.l     d1,d1                  ;  rowBytes*2
        sub.l     d0,d1                  ;  rowBytes*2-width*4
        move.l    d1,LS.P_y(a6)          ; SAVE P_y

        move.l    PS.rowByte(a6),d7      ; load rowBytes
        move.l    LS.Y1(a6),d6           ; load Y1

@do_y   move.l    LS.U_ix(a6),d0         ; LOAD U_ixB
        add.l     a1,d0                  ;  P+U_ixB
        move.l    d0,LS.U_ex(a6)         ; SAVE U_exB

@do_x   clr.w     d4                     ; U=0
        clr.w     d5                     ; V=0

        RGB2Y     (a3,d7.w),d3,d4,d5,(a0,d6.w); Convert pixel
        RGB2Y     (a3)+,d3,d4,d5,(a0)+        ; Convert pixel
        RGB2Y     (a3,d7.w),d3,d4,d5,(a0,d6.w); Convert pixel
        RGB2Y     (a3)+,d3,d4,d5,(a0)+        ; Convert pixel

        asr.w     #2,d4                  ; U>>=2
        asr.w     #2,d5                  ; V>>=2

        cmpi.w    #$FE40,d4              ; U>=-448
        bge.s     @okU                   ; if greater
        move.w    #$FE40,d4              ; U= -448
        bra.s     @doV                   ; save
@okU    cmpi.w    #$01C0,d4              ; U< 448
        blt.s     @doV                   ; if less
        move.w    #$01C0,d4              ; U= 448
```

Engineering:KlicsCode:CompPict:Colour.a

```
@doV    cmpi.w  #$FE40,d5               ; V>=-448
        bge.s   @okV                    ; if greater
        move.w  #$FE40,d5               ; V= -448
        bra.s   @end                    ; save
@okV    cmpi.w  #$01CC,d5               ; V< 448
        blt.s   @end                    ; if less
        move.w  #$01C0,d5               ; V= 448

@end    move.w  d4,(a1)+                ; Save U
        move.w  d5,(a2)+                ; Save V

        cmpa.l  LS.U_ex(a6),a1
        blt.w   @do_x

        add.l   LS.Y_y(a6),a0
        add.l   LS.P_y(a6),a3

        cmpa.l  LS.U_ey(a6),a1
        blt.w   @do_y

        movem.l (a7)+,d4-d7/a3-a5       ; restore registers
        unlk    a6                      ; remove locals
        rts     ; return

        ENDFUNC
*--------------------------------
        macro
        UV16    &AU, &AV, &SP, &UV

        move.l  (&AU)+,&SP
        move.l  (&AV)+,&UV
        UVOVER  &SP,&UV
        lsr.l   #5,&UV
        andi.l  #$03e003e0,&SP
        andi.l  #$001F001F,&UV
        or.l    &SP,&UV                 ; UV==$00UV00UV
        swap    &UV

        endm

        macro
        Y16x2   &AY,&IND,&UV

        move.l  &AY,d2                  ; (2+) Y=Y0Y1
        lsl.l   #5,d2                   ; (4) Y=Y0XXY1XX
        andi.l  #$FC00FC00,d2           ;
        or.w    &UV,d2                  ; (2) Y=Y1UV
        move.l  (&IND,d2.w*4),d1        ; (2+) d1=0123 (Y1)
        swap    d2                      ; (4) Y=Y0XX
        or.w    &UV,d2                  ; (2) Y=Y0UV
        move.l  (&IND,d2.w*4),d2        ; (2+) d2=0123 (Y0)

        endm

OUT16x2 FUNC    EXPORT

PS      RECORD  8
table   DS.L    1
pixmap  DS.L    1
Y       DS.L    1
U       DS.L    1
V       DS.L    1
```

```
width    DS.L        1
height   DS.L        1
rowByte  DS.L        1
pixmap2  DS.L        1
         ENDR
*
LS       RECORD      0,DECR
Y1       DS.L        1          ; sizeof(short)*Yrow              = 2*width
U_ex     DS.L        1          ; x end address                   = U+U_ix
U_ey     DS.L        1          ; y end address                   = U+width*height>>
U_ix     DS.L        1          ; sizeof(short)*UVrow             = width
Y_y      DS.L        1          ; sizeof(short)*Yrow              = 2*width
P_y      DS.L        1          ; 4*rowBytes-sizeof(long)*Prow    = 4*rowBytes-width
LSize    EQU         *
         ENDR
*
*        a0 - Y, a1 - U, a2 - V, a3 - pixmap, a4 - table, a5 - pixmap2
*        d0 - rgb00, d1 - rgb01, d2 - rgb10, d3 - rgb11, d4 - spare, d6 - old0, d7
*
         link        a6,#LS.LSize           ; inc, width, fend and rowend are loca
         movem.l     d4-d7/a3-a5,-(a7)      ; store registers
*
         move.l      PS.Y(a6),a0            ; Y=Yc
         move.l      PS.U(a6),a1            ; U=Uc
         move.l      PS.V(a6),a2            ; V=Vc
         move.l      PS.pixmap(a6),a3       ; pm=pixmap
         move.l      PS.table(a6),a4        ; tab=table
         adda.l      #$00020000,a4          ; tab+=32768 (longs)
         move.l      PS.pixmap2(a6),a5      ; pm2=pixmap2

         move.l      PS.width(a6),d0        ; LOAD width
         move.l      d0,LS.U_ix(a6)         ; SAVE U_ix
         move.l      PS.height(a6),d1       ; LOAD height
         mulu.w      d0,d1                  ;  width*height
         lsr.l       #1,d1                  ;  width*height/2
         add.l       a1,d1                  ;  U+width*height/2
         move.l      d1,LS.U_ey(a6)         ; SAVE U_ey
         add.l       d0,d0                  ;  width*2
         move.l      d0,LS.Y1(a6)           ; SAVE Y1
         move.l      d0,LS.Y_y(a6)          ; SAVE Y_y
         add.l       d0,d0                  ;  width*4
         move.l      PS.rowByte(a6),d1      ; LOAD rowBytes
         add.l       d1,d1                  ;  rowBytes*2
         add.l       d1,d1                  ;  rowBytes*4
         sub.l       d0,d1                  ;  rowBytes*4-width*4
         move.l      d1,LS.P_y(a6)          ; SAVE P_y

         move.l      PS.rowByte(a6),d5      ; load rowBytes
         clr.l       d6
         clr.l       d7

@do_y    move.l      LS.U_ix(a6),d0         ; LOAD U_ixB
         add.l       a1,d0                  ;  P+U_ixB
         move.l      d0,LS.U_ex(a6)         ; SAVE U_exB

@do_x    GETUV       a1,a2,d0,d4            ; d4=00UV00UV (10)

         GETY        (a0),a4,d4,d1,d2       ; calc d2,d1 pixel
         move.l      d2,(a3)+
         move.l      d1,(a3)
         add.l       d5,a3
         swap        d1
         move.l      d1,(a3)
```

```
        swap        d2
        move.l      d2,-(a3)
        add.l       d5,a3

        move.l      LS.Y1(a6),d0                ; load Yrow
        GETY        (a0,d0.w),a4,d4,d1,d2       ; calc d2,d1 pixels
        move.l      d2,(a3)+
        move.l      d1,(a3)
        add.l       d5,a3
        swap        d1
        move.l      d1,(a3)
        swap        d2
        move.l      d2,-(a3)

        swap        d4                          ; next UV
        addq.l      #4,a0                       ; next Ys
        add.l       #12,a3

        move.l      LS.Y1(a6),d0                ; load Yrow
        GETY        (a0,d0.w),a4,d4,d1,d2       ; calc d2,d1 pixels
        move.l      d1,(a3)
        move.l      d2,-(a3)
        sub.l       d5,a3
        swap        d2
        move.l      d2,(a3)+
        swap        d1
        move.l      d1,(a3)
        sub.l       d5,a3

        GETY        (a0)+,a4,d4,d1,d2
        move.l      d1,(a3)
        move.l      d2,-(a3)
        swap        d2
        sub.l       d5,a3
        move.l      d2,(a3)+
        swap        d1
        move.l      d1,(a3)+

        cmpa.l      LS.U_ex(a6),a1
        blt.w       @do_x

        add.l       LS.Y_y(a6),a0
        add.l       LS.P_y(a6),a3

        cmpa.l      LS.U_ey(a6),a1
        blt.w       @do_y

        movem.l     (a7)+,d4-d7/a3-a5           ; restore registers
        unlk        a6                          ; remove locals
        rts         ; return

        ENDFUNC
*-----------------------------------
        macro
        Y16         &AY,&IND,&UV

        move.l      &AY,d2                      ; (2+) Y=Y0Y1
        lsl.l       #5,d2                       ; (4) Y=Y0XXY1XX
        andi.l      #$FC00FC00,d2               ;
        or.w        &UV,d2                      ; (2) Y=Y1UV
        move.l      (&IND,d2.w*4),d1            ; (2+) d1=Y1
        swap        d2                          ; (4) Y=Y0XX
        or.w        &UV,d2                      ; (2) Y=Y0UV
```

```
        move.l      (&IND,d2.w*4),d2        ; (2+) d2=Y0
        move.w      d1,d2                   ; (2) d2=Y0Y1
*
        endm

CUT16   FUNC    EXPORT
*
PS      RECORD      8
table   DS.L        1
pixmap  DS.L        1
Y       DS.L        1
U       DS.L        1
V       DS.L        1
width   DS.L        1
height  DS.L        1
rowByte DS.L        1
pixmap2 DS.L        1
        ENDR
*
LS      RECORD      0,DECR
Y1      DS.L        1       ; sizeof(short)*Yrow            = 2*width
U_ex    DS.L        1       ; x end address                 = U+U_ix
U_ey    DS.L        1       ; y end address                 = U+width*height>>
U_ix    DS.L        1       ; sizeof(short)*UVrow           = width
Y_y     DS.L        1       ; sizeof(short)*Yrow            = 2*width
P_y     DS.L        1       ; 2*rowBytes-sizeof(long)*Prow  = 2*rowBytes-width
LSize   EQU         *
        ENDR
*
*       a0 - Y, a1 - U, a2 - V, a3 - pixmap, a4 - table, a5 - pixmap2
*       d0 - rgb00, d1 - rgb01, d2 - rgb10, d3 - rgb11, d4 - spare, d6 - old0, d7
*
        link        a6,#LS.LSize            ; inc, width, fend and rowend are loca
        movem.l     d4-d7/a3-a5,-(a7)       ; store registers
*
        move.l      PS.Y(a6),a0             ; Y=Yc
        move.l      PS.U(a6),a1             ; U=Uc
        move.l      PS.V(a6),a2             ; V=Vc
        move.l      PS.pixmap(a6),a3        ; pm=pixmap
        move.l      PS.table(a6),a4         ; tab=table
        adda.l      #$00020000,a4           ; tab+=32768 (longs)
        move.l      PS.pixmap2(a6),a5       ; pm2=pixmap2

        move.l      PS.width(a6),d0         ; LOAD width
        move.l      d0,LS.U_ix(a6)          ; SAVE U_ix
        move.l      PS.height(a6),d1        ; LOAD height
        mulu.w      d0,d1                   ;  width*height
        lsr.l       #1,d1                   ;  width*height/2
        add.l       a1,d1                   ;  U+width*height/2
        move.l      d1,LS.U_ey(a6)          ; SAVE U_ey
        add.l       d0,d0                   ;  width*2
        move.l      d0,LS.Y1(a6)            ; SAVE Y1
        move.l      d0,LS.Y_y(a6)           ; SAVE Y_y
        move.l      PS.rowByte(a6),d1       ; LOAD rowBytes
        add.l       d1,d1                   ;  rowBytes*2
        sub.l       d0,d1                   ;  rowBytes*2-width*2
        move.l      d1,LS.P_y(a6)           ; SAVE P_y

        move.l      PS.rowByte(a6),d5       ; load rowBytes
        clr.l       d6
        clr.l       d7

@do_y   move.l      LS.U_ix(a6),d0          ; LOAD U_ixB
```

```
        add.l       a1,d0                   ;  P+U_ixB
        move.l      d0,LS.U_ex(a6)          ; SAVE U_exB

@do_x   GETUV       a1,a2,d0,d4             ; d4=00UV00UV (10)

        GETY        (a0),a4,d4,d1,d2        ; calc d2,d1 pixel
        move.w      d1,d2
        move.l      d2,(a3)
        add.l       d5,a3

        move.l      LS.Y1(a6),d0            ; load Yrow
        GETY        (a0,d0.w),a4,d4,d1,d2   ; calc d2,d1 pixels
        move.w      d1,d2
        move.l      d2,(a3)+

        swap        d4                      ; next UV
        addq.l      #4,a0                   ; next Ys

        move.l      LS.Y1(a6),d0            ; load Yrow
        GETY        (a0,d0.w),a4,d4,d1,d2   ; calc d2,d1 pixels
        move.w      d1,d2
        move.l      d2,(a3)
        sub.l       d5,a3

        GETY        (a0)+,a4,d4,d1,d2
        move.w      d1,d2
        move.l      d2,(a3)+

        cmpa.l      LS.U_ex(a6),a1
        blt.w       @do_x

        add.l       LS.Y_y(a6),a0
        add.l       LS.P_y(a6),a3

        cmpa.l      LS.U_ey(a6),a1
        blt.w       @do_y

        movem.l     (a7)+,d4-d7/a3-a5       ; restore registers
        unlk        a6                      ; remove locals
        rts                                 ; return

        ENDFUNC
;----------------------------------
        END
```

```
*------------------------------------
*
*   © Copyright 1993 KLICS Limited
*   All rights reserved.
*
*   Written by: Adrian Lewis
*
*------------------------------------
*
*   68000 Fast RGB/YUV code
*
*------------------------------------
        include 'Traps.a'
        machine mc68030
*------------------------------------
        macro
        RGB2Y   &Apixel,&AY
*
*       d0 - pixel/r, d1 - g/2g+r, d2 - b, d3 - Y
*
        move.l  &Apixel,d0          ; pixel=*Apixel
        eor.l   #$00808080,d0       ; signed pixels

        move.b  d0,d2               ; b=pixel[3]
        ext.w   d2                  ; b is 8(16) bit

        move.w  d0,d1               ; g=pixel[2]
        asr.w   #7,d1               ; 2g is 9(16) bit

        swap    d0                  ; r=pixel[1]
        ext.w   d0                  ; r is 8(16) bit

        move.w  d2,d3               ; Y=b
        lsl.w   #3,d3               ; Y<<=3
        sub.w   d2,d3               ; Y-=b

        add.w   d0,d1               ; 2g+=r
        add.w   d1,d3               ; Y+=2g+r
        add.w   d1,d3               ; Y+=2g+r
        add.w   d1,d3               ; Y+=2g+r
        asr.w   #4,d3               ; Y>>=4
        add.w   d1,d3               ; Y+=2g+r
        move.w  d3,&AY              ; AY=Y is 10(16) bit
*
        endm
*------------------------------------
        macro
        RGB2UV  &AU,&AV
*
*       d0 - r, d2 - b, d3 - Y, d1 - U/V
*
        add.w   d0,d0               ; r is 9(16) bit
        add.w   d2,d2               ; b is 9(16) bit
        asr.w   #1,d3               ; Y is 9(16) bit
        move.w  d2,d1               ; U=b
        sub.w   d3,d1               ; U=b-Y
        move.w  d1,&AU              ; AU=U
        move.w  d0,d1               ; V=r
        sub.w   d3,d1               ; V=r-Y
        move.w  d1,&AV              ; AV=V
*
        endm
*------------------------------------
```

Engineering:KlicsCode:CompPict:Color2.a

```
        if   &TYPE('seg')≠'UNDEFINED' then
        seg          &seg
        endif

RGB2YUV2    FUNC     EXPORT
*
        link         a6,#0                    ; no local variables
        movem.l      d4-d7/a3,-(a7)           ; store registers
*
        move.l       $0008(a6),a3             ; pm=pixmap
        move.l       $000C(a6),a0             ; Y=Yc
        move.l       $0010(a6),a1             ; U=Uc
        move.l       $0014(a6),a2             ; V=Vc
        move.l       $0018(a6),d7             ; fend=area
        asl.l        #2,d7                    ; fend<<=2
        add.l        a3,d7                    ; fend+=pm
        move.l       $001C(a6),d4             ; width_b=width
        asl.l        #2,d4                    ; width_b<<=2
        move.l       $0020(a6),d5             ; inc_b=cols
        asl.l        #2,d5                    ; cols<<=2
        sub.l        d4,d5                    ; inc_b-=width_b
@do1    move.l       a3,d6                    ; rowend=pm
        add.l        d4,d6                    ; rowend+=width_b
@do2    rgb2y        (a3)+,(a0)+              ; rgb2y(pm++,Y++)
        rgb2uv       (a1)+,(a2)+              ; rgb2uv(U++,V++)
        rgb2y        (a3)+,(a0)+              ; rgb2y(pm++,Y++)
        cmpa.l       d6,a3                    ; rowend>pm
        blt.s        @do2                     ; while
        adda.l       d5,a3                    ; pm+=inc_b
        move.l       a3,d6                    ; rowend=pm
        add.l        d4,d6                    ; rowend+=width_b
@do3    rgb2y        (a3)+,(a0)+              ; rgb2y(pm++,Y++)
        cmpa.l       d6,a3                    ; rowend>pm
        blt.s        @do3                     ; while
        adda.l       d5,a3                    ; pm+=inc_b
        cmpa.l       d7,a3                    ; fend>pm
        blt.w        @do1                     ; while
*
        movem.l      (a7)+,d4-d7/a3           ; restore registers
        unlk         a6                       ; remove locals
        rts                                   ; return
*
        ENDFUNC
*--------------------------------
        macro
        FETCHY       &AY, &Y, &R, &G, &B
*
        move.l       &AY,&Y                   ; Y=*AY++
        add.l        &Y,&R                    ; RR+=Y12
        add.l        &Y,&G                    ; GG+=Y12
        add.l        &Y,&B                    ; BB+=Y12
*
        endm
*--------------------------------
        macro
        FIXOV        &V, &SP1, &SP2
*
        move.w       &V,&SP1
        clr.b        &SP1
        andi.w       #$3FFF,&SP1
        sne          &SP1
        btst         #13,&SP1
        seq          &SP2
```

```
        or.b            &SP1,&V
        and.w           &SP2,&V
        swap            &V
        move.w          &V,&SP1
        clr.b           &SP1
        andi.w          #$3FFF,&SP1
        sne             &SP1
        btst            #13,&SP1
        seq             &SP2
        or.b            &SP1,&V
        and.w           &SP2,&V
        swap            &V
*
        endm
*--------------------------------
        macro
        OVERFLOW        &A, &B, &SP1, &SP2
*
*       move.l          #$FF00FF00,&SP1         ; sp1=mask
*       move.l          &A,&SP2                 ; sp2=ovov (A)
*       and.l           &SP1,&SP2               ; sp2=o0o0 (A)
*       lsr.l           #8,&SP2                 ; sp2=0o0o (A)
*       and.l           &B,&SP1                 ; sp1=o0o0 (B)
*       or.l            &SP2,&SP1               ; sp1=oooo (BABA)
        move.l          &A,&SP1
        or.l            &B,&SP1
        andi.l          #$FF00FF00,&SP1
        beq.s           @ok                     ; if no overflow
        clr.w           &SP2                    ; AND=0
        FIXOV           &A,&SP1,&SP2            ; A1 overflow
        FIXOV           &B,&SP1,&SP2            ; B1 overflow
@ok
*
        endm
*--------------------------------
        macro
        MKRGB           &R, &G, &B, &ARGB
*
        lsl.l           #8,&G                   ; G=G0G0 (12)
        or.l            &B,&G                   ; G=GBGB (12)
        move.l          &R,&B                   ; B=0R0R (12)
        swap            &B                      ; B=0R0R (21)
        move.w          &G,&B                   ; B=0RGB (2)
        swap            &G                      ; G=GBGB (21)
        move.w          &G,&R                   ; R=0RGB (1)
        move.l          &R,&ARGB                ; *RGB++=rgb (1)
        move.l          &B,&ARGB                ; *RGB++=rgb (2)
*
        endm
*--------------------------------
        macro
        DUPVAL          &V0, &V1
*
        move.w          &V0,&V1                 ; v1=v0
        swap            &V0
        move.w          &V1,&V0                 ; dup v0
        move.l          &V0,&V1                 ; dup v1
*
        endm
*--------------------------------
        macro
        UV2RGB3         &AU,&AV
*
```

```
*       d1 - ra, d2 - ga, d3 - ba, d4 - rb, d5 - gb/512, d6 - bb
*
        move.w      #512,d5                     ; d5=512
        move.w      &AU,d2                      ; U=*AU++
        add.w       d2,d2                       ; U is 10(16) bits
        move.w      d2,d3                       ; ba=U
        add.w       d3,d2                       ; ga=2U
        add.w       d3,d2                       ; ga=3U
        add.w       d5,d3                       ; ba+=512
        DUPVAL      d3,d6                       ; ba=bb=BB
        asr.w       #4,d2                       ; ga=3U>>4
        move.w      &AV,d1                      ; V=*AV++
        add.w       d1,d2                       ; ga+=V
        add.w       d1,d1                       ; ra*=2
        add.w       d5,d1                       ; ra+=512
        DUPVAL      d1,d4                       ; ra=rb=RR
        sub.w       d2,d5                       ; gb=512-ga
        DUPVAL      d5,d2                       ; ga=gb=GG
*
        endm
*-------------------------------
        if  &TYPE('seg')≠'UNDEFINED' then
        seg         &seg
        endif

YUV2RGB2    FUNC        EXPORT
*
PS      RECORD      8
pixmap  DS.L        1
Y       DS.L        1
U       DS.L        1
V       DS.L        1
area    DS.L        1
width   DS.L        1
cols    DS.L        1
        ENDR
*
LS      RECORD      0,DECR
inc     DS.L        1
width   DS.L        1
fend    DS.L        1
count   DS.L        1
LSize   EQU         *
        ENDR
*
*       a0 - Y0, a1 - Y1, a2 - U, a3 - V, a4 - pm0, a5 - pm1
*       d0..6 - used, d7 - count
*
        link        a6,#LS.LSize                ; inc, width, fend and rowend are loca
        movem.l     d4-d7/a3-a5,-(a7)           ; store registers
*
        move.l      PS.pixmap(a6),a4            ; pm0=pixmap
        move.l      a4,a5                       ; pm1=pm0
        move.l      PS.Y(a6),a0                 ; Y0=Yc
        move.l      a0,a1                       ; Y1=Y0
        move.l      PS.U(a6),a2                 ; U=Uc
        move.l      PS.V(a6),a3                 ; V=Vc
        move.l      PS.area(a6),d7              ; fend=area
        lsl.l       #2,d7                       ; fend<<=2
        add.l       a4,d7                       ; fend+=pm0
        move.l      d7,LS.fend(a6)              ; save fend
        move.l      PS.width(a6),d5             ; width=width
        move.l      d5,d7                       ; count=width
```

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```
        asr.l     #1,d7                      ; count>>=1
        subq.l    #1,d7                      ; count-=1
        move.l    d7,PS.width(a6)            ; save width
        add.l     d5,d5                      ; width*=2
        add.l     d5,a1                      ; Y1+=width
        add.l     d5,d5                      ; width*=2
        move.l    d5,LS.width(a6)            ; save width
        move.l    PS.cols(a6),d4             ; inc=cols
        lsl.l     #2,d4                      ; inc<<=2
        add.l     d4,a5                      ; pm1+=inc
        add.l     d4,d4                      ; cols*=2
        sub.l     d5,d4                      ; inc now 2*cols-width bytes
        move.l    d4,LS.inc(a6)              ; save inc
@do     UV2RGB3   (a2)+,(a3)+                ; uv2rgb(*U++,*V++)
        FETCHY    (a0)+,d0,d1,d2,d3          ; add Ya to RGB values
        FETCHY    (a1)+,d0,d4,d5,d6          ; add Yb to RGB values
        move.w    #$3FFF,d0                  ; d0=mask
        lsr.l     #2,d1                      ; d1 8(16) bits
        and.w     d0,d1                      ; d1 masked
        lsr.l     #2,d2                      ; d2 8(16) bits
        and.w     d0,d2                      ; d2 masked
        lsr.l     #2,d3                      ; d3 8(16) bits
        and.w     d0,d3                      ; d3 masked
        lsr.l     #2,d4                      ; d4 8(16) bits
        and.w     d0,d4                      ; d4 masked
        lsr.l     #2,d5                      ; d5 8(16) bits
        and.w     d0,d5                      ; d5 masked
        lsr.l     #2,d6                      ; d6 8(16) bits
        and.w     d0,d6                      ; d6 masked
        move.l    d1,d0
        or.l      d2,d0
        or.l      d3,d0
        or.l      d4,d0
        or.l      d5,d0
        or.l      d6,d0
        andi.l    #$FF00FF00,d0
        bne.s     @over                      ; if overflow
@ok     MKRGB     d1,d2,d3,(a4)+             ; save RGBa
        MKRGB     d4,d5,d6,(a5)+             ; save RGBb
        dbf       d7,@do                     ; while
        adda.l    LS.inc(a6),a4              ; pm0+=inc
        adda.l    LS.inc(a6),a5              ; pm1+=inc
        adda.l    LS.width(a6),a0            ; Y0+=width
        exg.l     a0,a1                      ; Y1<->Y0
        move.l    PS.width(a6),d7            ; count=width
        cmpa.l    LS.fend(a6),a4             ; pm0<fend
        blt.w     @do                        ; while

        movem.l   (a7)+,d4-d7/a3-a5          ; restore registers
        unlk      a6                         ; remove locals
        rts                                  ; return
@over   move.l    d7,LS.count(a6)            ; save count
        clr.w     d7                         ; AND=0

        FIXOV     d1,d0,d7                   ; A overflow
        FIXOV     d2,d0,d7                   ; B overflow
        FIXOV     d3,d0,d7                   ; A overflow
        FIXOV     d4,d0,d7                   ; B overflow
        FIXOV     d5,d0,d7                   ; A overflow
        FIXOV     d6,d0,d7                   ; B overflow
        move.l    LS.count(a6),d7            ; restore count
        bra       @ok
```

```
        ENDFUNC
*-------------------------------
        if  &TYPE('seg')≠'UNDEFINED' then
        seg         &seg
        endif

GREY2Y  FUNC    EXPORT
*
PS      RECORD      8
pixmap  DS.L        1
Y       DS.L        1
area    DS.L        1
width   DS.L        1
cols    DS.L        1
        ENDR
*
*   d0 - vvvv, d1 - v0v1, d2 - v2v3, d3 - xor, d4 - width, d5 - inc, d6 - rowend,
*   a0 - pm, a1 - Y
*
        link        a6,#0                   ; no local variables
        movem.l     d4-d7,-(a7)             ; store registers
*
        move.l      PS.pixmap(a6),a0        ; pm=pixmap
        move.l      PS.Y(a6),a1             ; Y=Yc
        move.l      PS.area(a6),d7          ; fend=area
        add.l       a0,d7                   ; fend+=pm
        move.l      PS.width(a6),d4         ; width_b=width
        move.l      PS.cols(a6),d5          ; inc_b=cols
        sub.l       d4,d5                   ; inc_b-=width_b
        move.l      #$7F7F7F7F,d3           ; xor=$7F7F7F7F
@do1    move.l      a0,d6                   ; rowend=pm
        add.l       d4,d6                   ; rowend+=width_b
@do2    move.l      (a0)+,d0                ; vvvv=*pm
        eor.l       d3,d0                   ; vvvv is signed
        move.w      d0,d2                   ; d2=v2v3
        asr.w       #6,d2                   ; d2=v2 (10 bits)
        swap        d2                      ; d2=v2??
        move.b      d0,d2                   ; d2=v2v3
        ext.w       d2                      ; v3 extended
        lsl.w       #2,d2                   ; d2=v2v3 (10 bits)
        swap        d0                      ; d0=v0v1
        move.w      d0,d1                   ; d1=v0v1
        asr.w       #6,d1                   ; d1=v0 (10 bits)
        swap        d1                      ; d1=v0??
        move.b      d0,d1                   ; d1=v0v1
        ext.w       d1                      ; v1 extended
        lsl.w       #2,d1                   ; d1=v0v1 (10 bits)
        move.l      d1,(a1)+                ; *Y=d1
        move.l      d2,(a1)+                ; *Y=d2
        cmpa.l      d6,a0                   ; rowend>pm
        blt.s       @do2                    ; while
        adda.l      d5,a0                   ; pm+=inc_b
        cmpa.l      d7,a0                   ; fend>pm
        blt.s       @do1                    ; while
*
        movem.l     (a7)+,d4-d7             ; restore registers
        unlk        a6                      ; remove locals
        rts                                 ; return
*
        ENDFUNC
*-------------------------------
        if  &TYPE('seg')≠'UNDEFINED' then
        seg         &seg
```

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```
        endif

Y2GREY  FUNC     EXPORT
*
PS      RECORD        8
pixmap  DS.L          1
Y       DS.L          1
height  DS.L          1
width   DS.L          1
cols    DS.L          1
        ENDR
*
*   d0- spare, d1 - v43, d2 - v21, d3 - spare, d4 - width, d5 - inc, d6 - count, d
*   a0 - pm, a1 - Y
*
        link          a6,#0                    ; no local variables
        movem.l       d4-d7,-(a7)              ; store registers
*
        move.l        PS.pixmap(a6),a0         ; pm=pixmap
        move.l        PS.Y(a6),a1              ; Y=Yc
        move.l        PS.height(a6),d7         ; long height
        subq.l        #1,d7                    ; height-=1
        move.l        PS.width(a6),d4          ; long width
        move.l        PS.cols(a6),d5           ; long inc=cols
        sub.l         d4,d5                    ; inc-=width
        lsr.l         #2,d4                    ; width>>=2 (read 4 values)
        subq.l        #1,d4                    ; width-=1
@do1    move.l        d4,d6                    ; count=width
@do2    move.l        (a1)+,d0                 ; d0=x4x3
        move.l        (a1)+,d1                 ; d1=x2x1
        move.l        #$01FF01FF,d2            ; d2=511
        move.l        d2,d3                    ; d3=511
        sub.l         d0,d2                    ; unsigned d2
        sub.l         d1,d3                    ; unsigned d3
        lsr.l         #2,d2
        lsr.l         #2,d3
        move.l        d2,d0
        or.l          d3,d0
        andi.l        #$3F003F00,d0
        bne.s         @over                    ; if no overflow
@ok     lsl.w         #8,d3                    ; d3=0210
        lsl.w         #8,d2                    ; d2=0430
        lsr.l         #8,d3                    ; d3=0021
        lsl.l         #8,d2                    ; d2=4300
        or.l          d3,d2                    ; d2=4321
        move.l        d2,(a0)+                 ; *pm=d2
        dbf           d6,@do2                  ; while -1!=--count
        adda.l        d5,a0                    ; pm+=inc_b
        dbf           d7,@do1                  ; while -1!=--height
*
        movem.l       (a7)+,d4-d7              ; restore registers
        unlk          a6                       ; remove locals
        rts                                    ; return
@over   clr.w         d1                       ; AND=0
        FIXOV         d2,d0,d1                 ; A overflow
        FIXOV         d3,d0,d1                 ; B overflow
        bra.s         @ok
*
        ENDFUNC
*---------------------------------
        macro
        GGG           &V,&SP1,&SP2,&AV
*
```

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```
        move.l      &V,&SP2                  ; SP2=0102
        lsl.l       #8,&SP2                  ; SP2=1020
        or.l        &V,&SP2                  ; SP2=1122
        move.l      &V,&SP1                  ; SP1=0102
        swap        &SP1                     ; SP1=0201
        move.w      &SP2,&SP1                ; SP1=0222
        swap        &SP2                     ; SP2=2211
        move.w      &SP2,&V                  ; V=0111
        move.l      &V,&AV                   ; *pm=V
        move.l      &SP1,&AV                 ; *pm=SP1
*
        endm
*-----------------------------------
        if  &TYPE('seg')≠'UNDEFINED' then
        seg         &seg
        endif

Y2GGG   FUNC    EXPORT
*
PS      RECORD      8
pixmap  DS.L        1
Y       DS.L        1
lines   DS.L        1
width   DS.L        1
cols    DS.L        1
        ENDR
*
*   d0 - v, d4 - width, d5 - inc, d6 - count, d7 - lines
*   a0 - pm, a1 - Y
*
        link        a6,#0                    ; no local variables
        movem.l     d4-d7,-(a7)              ; store registers
*
        move.l      PS.pixmap(a6),a0         ; pm=pixmap
        move.l      PS.Y(a6),a1              ; Y=Yc
        move.l      PS.lines(a6),d7          ; long lines
        subq.l      #1,d7                    ; lines-=1
        move.l      PS.width(a6),d4          ; long width
        move.l      PS.cols(a6),d5           ; inc=cols
        sub.l       d4,d5                    ; inc-=width
        lsl.l       #2,d5                    ; inc (bytes)
        lsr.l       #2,d4                    ; width>>=2
        subq.l      #1,d4                    ; width-=1
@do1    move.l      d4,d6                    ; count=width
@do2    move.l      (a1)+,d0                 ; d0=x1x2 (10 bits signed)
        move.l      (a1)+,d1                 ; d1=x3x4 (10 bits)
        move.l      #$02000200,d3            ; d3=plus
        add.l       d3,d0                    ; d0=x1x2 (unsigned)
        add.l       d3,d1                    ; d1=x3x4 (unsigned)
        lsr.l       #2,d0                    ; d0=x1x2 (10,8 bits)
        lsr.l       #2,d1                    ; d1=x3x4 (10,8 bits)
        move.w      #$3FFF,d2                ; d2=mask
        and.w       d2,d0                    ; mask d0
        and.w       d2,d1                    ; mask d1
        move.l      d0,d2
        or.l        d1,d2
        andi.l      #$FF00FF00,d2
        bne.s       @over                    ; if no overflow
@ok     GGG         d0,d2,d3,(a0)+
        GGG         d1,d2,d3,(a0)+
        dbf         d6,@do2                  ; while -1!=--count
        adda.l      d5,a0                    ; pm+=inc_b
        dbf         d7,@do1                  ; while -1!=--lines
```

```
        movem.l    (a7)+,d4-d7          ; restore registers
        unlk       a6                   ; remove locals
        rts                             ; return
@over   clr.w      d3                   ; AND=0
        FIXOV      d0,d2,d3             ; A overflow
        FIXOV      d1,d2,d3             ; B overflow
        bra.w      @ok

        ENDFUNC
;-------------------------------
        macro
        MXRGB2     &R, &G, &B, &ARGB, &ROW, &XX

        lsl.l      #8,&G                ; G=G0G0 (12)
        or.l       &B,&G                ; G=GBGB (12)
        move.l     &R,&B                ; B=0R0R (12)
        swap       &B                   ; B=0R0R (21)
        move.w     &G,&B                ; B=0RGB (2)
        swap       &G                   ; G=GBGB (21)
        move.w     &G,&R                ; R=0RGB (1)

        andi.l     #$FFFEFEFE,&R        ; 7 bits for interpolation
        andi.l     #$FFFEFEFE,&B        ; 7 bits for interpolation

        move.l     &R,&G                ; G=RGB(1)
        add.l      &B,&G                ; G+=RGB(2)
        lsr.l      #1,&G                ; G/=2

        move.l     &B,&XX               ; XX=RGB(2)
        sub.l      &R,&XX               ; XX-=RGB(1)
        lsr.l      #1,&XX               ; XX/=2
        add.l      &B,&XX               ; XX+=B

        move.l     &R,(&ARGB)+          ; *RGB++=rgb (1)
        move.l     &G,(&ARGB)+          ; *RGB++=rgb (1.5)
        move.l     &B,(&ARGB)+          ; *RGB++=rgb (2)
        move.l     &B,(&ARGB)+          ; *RGB++=rgb (2.5)

        add.l      &ROW,&ARGB
        sub.l      #16,&ARGB

        move.l     &R,(&ARGB)+          ; *RGB++=rgb (1)
        move.l     &G,(&ARGB)+          ; *RGB++=rgb (1.5)
        move.l     &B,(&ARGB)-          ; *RGB++=rgb (2)
        move.l     &B,(&ARGB)+          ; *RGB++=rgb (2.5)

        sub.l      &ROW,&ARGB

        endm
;-------------------------------
        if  &TYPE('seg')#'UNDEFINED' then
        seg        &seg
        endif

YUV2RGB3  FUNC     EXPORT
;
PS        RECORD   8
pixmap    DS.L     1
Y         DS.L     1
U         DS.L     1
V         DS.L     1
area      DS.L     1
```

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```
width   DS.L        1
cols    DS.L        1
        ENDR
*
LS      RECORD      0,DECR
inc     DS.L        1
width   DS.L        1
fend    DS.L        1
count   DS.L        1
row     DS.L        1
LSize   EQU         *
        ENDR
*
*       a0 - Y0, a1 - Y1, a2 - U, a3 - V, a4 - pm0, a5 - pm1
*       d0..6 - used, d7 - count
*
        link        a6,#LS.LSize            ; inc, width, fend and rowend are loca
        movem.l     d4-d7/a3-a5,-(a7)       ; store registers
*
        move.l      PS.pixmap(a6),a4        ; pm0=pixmap
        move.l      a4,a5                   ; pm1=pm0
        move.l      PS.Y(a6),a0             ; Y0=Yc
        move.l      a0,a1                   ; Y1=Y0
        move.l      PS.U(a6),a2             ; U=Uc
        move.l      PS.V(a6),a3             ; V=Vc
        move.l      PS.area(a6),d7          ; fend=area
        lsl.l       #2,d7                   ; fend<<=2
        add.l       a4,d7                   ; fend+=pm0
        move.l      d7,LS.fend(a6)          ; save fend
        move.l      PS.width(a6),d5         ; width=width
        move.l      d5,d7                   ; count=width
        asr.l       #1,d7                   ; count>>=1
        subq.l      #1,d7                   ; count-=1
        move.l      d7,PS.width(a6)         ; save width
        add.l       d5,d5                   ; width*=2
        add.l       d5,a1                   ; Y1+=width
        add.l       d5,d5                   ; width*=2
        move.l      d5,LS.width(a6)         ; save width
        move.l      PS.cols(a6),d4          ; inc=cols
        lsl.l       #2,d4                   ; inc<<=2
        move.l      d4,LS.row(a6)           ;*NEW save row
        add.l       d4,a5                   ; pm1+=inc
        add.l       d4,a5                   ;*NEW pm1+=inc
        add.l       d4,d4                   ; cols*=2
        add.l       d4,d4                   ;*NEW cols*=2
        sub.l       d5,d4                   ; inc now 4*cols-width bytes
        sub.l       d5,d4                   ;*NEW  inc now 4*cols-width bytes (wid
        move.l      d4,LS.inc(a6)           ; save inc
@do     UV2RGB3     (a2)+,(a3)+             ; uv2rgb(*U++,*V++)

        FETCHY      (a0)+,d0,d1,d2,d3       ; add Ya to RGB values
        FETCHY      (a1)+,d0,d4,d5,d6       ; add Yb to RGB values

        move.w      #$3FFF,d0               ; d0=mask
        lsr.l       #2,d1                   ; d1 8(16) bits
        and.w       d0,d1                   ; d1 masked
        lsr.l       #2,d2                   ; d2 8(16) bits
        and.w       d0,d2                   ; d2 masked
        lsr.l       #2,d3                   ; d3 8(16) bits
        and.w       d0,d3                   ; d3 masked
        lsr.l       #2,d4                   ; d4 8(16) bits
        and.w       d0,d4                   ; d4 masked
        lsr.l       #2,d5                   ; d5 8(16) bits
```

```
        and.w       d0.d5                         ; d5 masked
        lsr.l       #2.d6                         ; d6 8(16) bits
        and.w       d0.d6                         ; d6 masked

        move.l      d1.d0
        or.l        d2.d0
        or.l        d3.d0
        or.l        d4.d0
        or.l        d5.d0
        or.l        d6.d0
        andi.l      #$FF00FF00.d0
        bne.w       @over                         ; if overflow

@ok     MKRGB2      d1.d2.d3.a4.LS.row(a6).d0    ;*NEW save RGBa
        MKRGB2      d4.d5.d6.a5.LS.row(a6).d0    ;*NEW save RGBb
        dbf         d7.@do                        ; while
        adda.l      LS.inc(a6).a4                 ; pm0+=inc
        adda.l      LS.inc(a6).a5                 ; pm1+=inc
        adda.l      LS.width(a6),a0               ; Y0+=width
        exg.l       a0.a1                         ; Y1<->Y0
        move.l      PS.width(a6).d7               ; count=width
        cmpa.l      LS.fend(a6).a4                ; pm0<fend
        blt.w       @do                           ; while
*
        movem.l     (a7)+.d4-d7/a3-a5             ; restore registers
        unlk        a6                            ; remove locals
        rts                                       ; return
@over   move.l      d7,LS.count(a6)               ; save count
        clr.w       d7                            ; AND=0
        FIXOV       d1,d0,d7                      ; A overflow
        FIXOV       d2,d0,d7                      ; B overflow
        FIXOV       d3,d0,d7                      ; A overflow
        FIXOV       d4,d0,d7                      ; B overflow
        FIXOV       d5,d0,d7                      ; A overflow
        FIXOV       d6,d0,d7                      ; B overflow
        move.l      LS.count(a6).d7               ; restore count
        bra         @ok
*
        ENDFUNC
*-----------------------------------
        macro
        FETCHY2     &AY, &Y, &R, &G, &B
*
        move.l      &AY,&Y                        ;Y
        asr.w       #2,&Y
        swap        &Y
        asr.w       #2,&Y
        swap        &Y                            ;Y is       -128 to +127
        add.l       &Y,&R                         ;RED, Get (Y+ 2V + 512) for Red = (Y +
        add.l       &Y,&G                         ;GREEN, Get (Y + (512 - (6U/16)) - V)
        add.l       &Y,&B                         ;BLUE,Get (Y + (2U + 512) for Blue = (
*
        endm
*-----------------------------------
        macro
        UV2RGB4     &AU,&AV
*
        move.w      &AU,d2                  ; U
        and.w       #$03FF,d2
        move.l      (a6,d2.w*8),d3                ;BLUE,Get (2U + 512)/4 for Blue = (Y +
        move.l      d3,d6                         ;Dup for second pair
        move.l      4(a6,d2.w*8),d5               ;GREEN, Get (512 - (6U/16))/4 for Gree
        move.w      &AV,d1                  ; V
```

```
        move.w      d1,d4
        asr.w       #2,d1
        sub.w       d1,d5                       ;GREEN, Get (512 - (6U/16) - V)/4 for
        move.w      d5,d2
        swap        d5
        move.w      d2,d5
        move.l      d5,d2                       ;Dup for second pair

        and.w       #$03FF,d4
        move.l      (a6,d4.w*8),d4              ;RED, Get (2V + 512)/4 for Red = (Y +
        move.l      d4,d1
*
        endm
*-------------------------------------

MKRGB2SUB   FUNC    EXPORT
*
        MKRGB2      d1,d2,d3,a4,d7,d0       ;*NEW save RGBa
        MKRGB2      d4,d5,d6,a5,d7,d0       ;*NEW save RGBb
        rts
*
        ENDFUNC

OVERSUB FUNC        EXPORT
*
        move.l      d1,d0
        or.l        d2,d0
        or.l        d3,d0
        or.l        d4,d0
        or.l        d5,d0
        or.l        d6,d0
        andi.l      #$FF00FF00,d0
        bne.s       @over                       ; if overflow
@ok     rts
@over   move.l      d7,-(sp)                    ; save count
        clr.w       d7                          ; AND=0
        FIXOV       d1,d0,d7                    ; A overflow
        FIXOV       d2,d0,d7                    ; B overflow
        FIXOV       d3,d0,d7                    ; A overflow
        FIXOV       d4,d0,d7                    ; B overflow
        FIXOV       d5,d0,d7                    ; A overflow
        FIXOV       d6,d0,d7                    ; B overflow
        move.l      (sp)+,d7                    ; restore count
        bra         @ok
*
        ENDFUNC

UV2RGB4SUB  FUNC    EXPORT
*
        UV2RGB4     (a2)+,(a3)+                 ; uv2rgb(*U++,*V++)
        rts
*
        ENDFUNC

FETCHY2SUB  FUNC    EXPORT
*
        FETCHY2     (a0)+,d0,d1,d2,d3           ; add Ya to RGB values
        FETCHY2     (a1)+,d0,d4,d5,d6           ; add Yb to RGB values
        rts
*
        ENDFUNC

        if  &TYPE('seg')≠'UNDEFINED' then
```

Engineering:KlicsCode:CompPict:Color2.a

```
        seg         &seg
        endif

YUV2RGB5    FUNC    EXPORT
*
PS      RECORD      8
Table   DS.L        1
pixmap  DS.L        1
Y       DS.L        1
U       DS.L        1
V       DS.L        1
area    DS.L        1
width   DS.L        1
cols    DS.L        1
        ENDR
*
LS      RECORD      0,DECR
inc     DS.L        1
width   DS.L        1
fend    DS.L        1
count   DS.L        1
row     DS.L        1
LSize   EQU         *
        ENDR
*
*       a0 - Y0, a1 - Y1, a2 - U, a3 - V, a4 - pm0, a5 - pm1
*       d0..6 - used, d7 - count
*
        link        a6,#LS.LSize            ; inc, width, fend and rowend are loca
        movem.l     d4-d7/a3-a5,-(a7)       ; store registers
*
        move.l      PS.pixmap(a6),a4        ; pm0=pixmap
        move.l      a4,a5                   ; pm1=pm0
        move.l      PS.Y(a6),a0             ; Y0=Yc
        move.l      a0,a1                   ; Y1=Y0
        move.l      PS.U(a6),a2             ; U=Uc
        move.l      PS.V(a6),a3             ; V=Vc
        move.l      PS.area(a6),d7          ; fend=area
        lsl.l       #2,d7                   ; fend<<=2
        add.l       a4,d7                   ; fend+=pm0
        move.l      d7,LS.fend(a6)          ; save fend
        move.l      PS.width(a6),d5         ; width=width
        move.l      d5,d7                   ; count=width
        asr.l       #1,d7                   ; count>>=1
        subq.l      #1,d7                   ; count-=1
        move.l      d7,PS.width(a6)         ; save width

        add.l       d5,d5                   ; width*=2
        add.l       d5,a1                   ; Y1+=width
        add.l       d5,d5                   ; width*=2
        move.l      d5,LS.width(a6)         ; save width
        move.l      PS.cols(a6),d4          ; inc=cols
        lsl.l       #2,d4                   ; inc<<=2
        move.l      d4,LS.row(a6)           ;*NEW save row
        add.l       d4,a5                   ; pm1+=inc
        add.l       d4,a5                   ;*NEW pm1+=inc
        add.l       d4,d4                   ; cols*=2
        add.l       d4,d4                   ;*NEW cols*=2
        sub.l       d5,d4                   ; inc now 4*cols-width bytes
        sub.l       d5,d4                   ;*NEW  inc now 4*cols-width bytes (wid
        move.l      d4,LS.inc(a6)           ; save inc

@do     move.l      d7,-(sp)
```

Engineering:KlicsCode:CompPict:Color2.a

```
        move.l      a6,-(sp)
        move.l      LS.row(a6),d7
        move.l      PS.Table(a6),a6
        UV2RGB4     (a2)+,(a3)+             ; uv2rgb(*U++,*V++)

        FETCHY2     (a0)+,d0,d1,d2,d3       ; add Ya to RGB values
        FETCHY2     (a1)+,d0,d4,d5,d6       ; add Yb to RGB values

        move.l      d1,d0
        or.l        d2,d0
        or.l        d3,d0
        or.l        d4,d0
        or.l        d5,d0
        or.l        d6,d0
        andi.l      #$FF00FF00,d0
        bne.w       @over                   ; if overflow

@ok     MKRGB2      d1,d2,d3,a4,d7,d0       ;*NEW save RGBa
        MKRGB2      d4,d5,d6,a5,d7,d0       ;*NEW save RGBb
        move.l      (sp)+,a6
        move.l      (sp)+,d7

        dbf         d7,@do                  ; while

        adda.l      LS.inc(a6),a4           ; pm0+=inc
        adda.l      LS.inc(a6),a5           ; pm1+=inc
        adda.l      LS.width(a6),a0         ; Y0+=width
        exg.l       a0,a1                   ; Y1<->Y0
        move.l      PS.width(a6),d7         ; count=width
        cmpa.l      LS.fend(a6),a4          ; pm0<fend
        blt.s       @do                     ; while
*
        movem.l     (a7)+,d4-d7/a3-a5       ; restore registers
        unlk        a6                      ; remove locals
        rts                                 ; return
@over   move.l      d7,LS.count(a6)         ; save count
        clr.w       d7                      ; AND=0
        FIXOV       d1,d0,d7                ; A overflow
        FIXOV       d2,d0,d7                ; B overflow
        FIXOV       d3,d0,d7                ; A overflow
        FIXOV       d4,d0,d7                ; B overflow
        FIXOV       d5,d0,d7                ; A overflow
        FIXOV       d6,d0,d7                ; B overflow
        move.l      LS.count(a6),d7         ; restore count
        bra         @ok
*
        ENDFUNC
*---------------------------------
        END
```

```
/*******************************
 *
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 *
 * Written by: Adrian Lewis
 *
 ********************************/
/*
	Analyse CLUT setup and pick appropriate
	YUV->RGB converter/display driver. Create
	any tables necessary.
*/

#include <QuickDraw.h>
#include <Memory.h>

#define Y_LEVELS	64
#define UV_LEVELS	16

#define absv(v) ((v)<0?-(v):(v))
#define NewPointer(ptr,type,size) \
	saveZone=GetZone(); \
	SetZone(SystemZone()); \
	if (nil==(ptr=(type)NewPtr(size))) { \
		SetZone(ApplicZone()); \
		if (nil==(ptr=(type)NewPtr(size))) { \
			SetZone(saveZone); \
			return(MemoryError()); \
		} \
	} \
	SetZone(saveZone);

typedef struct {
	char	y, u, v;
} YUV_Clut;

/*
unsigned char *
ColourClut(CTabHandle clut)
{
	int	size, y, u, v, r, g, b, i;
	unsigned char *table;
	YUV_Clut	*yuv_clut;

	size=(*clut)->ctSize;
	table=(unsigned char *)NewPtr(Y_LEVELS*UV_LEVELS*UV_LEVELS);
	yuv_clut=(YUV_Clut *)NewPtr(size*sizeof(YUV_Clut));

	for(i=0;i<=size;i++) {
		r=((*clut)->ctTable[i].rgb.red>>8)-128;
		g=((*clut)->ctTable[i].rgb.green>>8)-128;
		b=((*clut)->ctTable[i].rgb.blue>>8)-128;

		yuv_clut[i].y= (306*r + 601*g + 117*b)>>10;
		yuv_clut[i].u= (512*r - 429*g - 83*b)>>10;
		yuv_clut[i].v= (-173*r - 339*g + 512*b)>>10;
	}
	for(y=-Y_LEVELS/2;y<Y_LEVELS/2-1;y++)
	for(u=-UV_LEVELS/2;u<UV_LEVELS/2-1;u++)
	for(v=-UV_LEVELS/2;v<UV_LEVELS/2-1;v++) {
		int	index,error,error2,points, Y, U, V;
```

```
        Y=y<<4;
        U=u<<5;
        V=v<<5;

        index=0;
        error=131072;
        error2=131072;
        points=0;
        for(i=0;i<=size;i++) {
            int pts=0, err=0;

            if (yuv_clut[i].y>=Y && yuv_clut[i].y<Y+16)
                pts+=1;
            err+=absv(yuv_clut[i].y-Y);

            if (yuv_clut[i].u>=U && yuv_clut[i].u<U+32)
                pts+=1;
            err+=absv(yuv_clut[i].u-U);

            if (yuv_clut[i].v>=V && yuv_clut[i].v<V+32)
                pts+=1;
            err+=absv(yuv_clut[i].v-V);

            if (pts>points || (pts==points && err<error)) {
                error=err;
                index=i;
                points=pts;
            }
        }
        i=((y&0x1F)<<8)|((u&0xF)<<4)|(v&0xF);
        table[i]=(unsigned char)index;
    }
    DisposePtr((Ptr)yuv_clut);
    return table;
}*/

typedef union {
    long    pixel;
    unsigned char   rgb[4];
} Pixel;
/*
unsigned long *
ColourClut(CTabHandle clut)
{
    long    size, y, u, v, r, g, b, ro, go, bo,i;
    Pixel   *table;

    size=(*clut)->ctSize;
    table=(Pixel *)NewPtr(Y_LEVELS*UV_LEVELS*UV_LEVELS*sizeof(long));

    for(y=-Y_LEVELS/2;y<Y_LEVELS/2-1;y++)
    for(u=-UV_LEVELS/2;u<UV_LEVELS/2-1;u++)
    for(v=-UV_LEVELS/2;v<UV_LEVELS/2-1;v++) {
        Pixel   px;
        long    base, dith;

        r = 32768L + ((y<<9) + 1436L*u <<2);
        g = 32768L + ((y<<9) - 731L*u - 352L*v <<2);
        b = 32768L + ((y<<9) + 1815L*v <<2);

        r=r<0?0:r>65534?65534:r;
        g=g<0?0:g>65534?65534:g;
        b=b<0?0:b>65534?65534:b;
```

```
        ro=r%13107; r=r/13107;
        go=g%13107; g=g/13107;
        bo=b%13107; b=b/13107;

        base=215-(36*r+6*g+b);

        dith=base-(ro>2621?36:0)-(go>7863?6:0)-(bo>10484?1:0);
        px.rgb[0]=dith==215?255:dith;

        dith=base-(ro>5242?36:0)-(go>10484?6:0)-(bo>2621?1:0);
        px.rgb[1]=dith==215?255:dith;

        dith=base-(ro>7863?36:0)-(go>2621?6:0)-(bo>5242?1:0);
        px.rgb[2]=dith==215?255:dith;

        dith=base-(ro>10484?36:0)-(go>5242?6:0)-(bo>7863?1:0);
        px.rgb[3]=dith==215?255:dith;

        i=((y&0x3F)<<8)|((u&0xF)<<4)|(v&0xF);

        table[i].pixel=px.pixel;
    }
    return (unsigned long*)table;
}*/

typedef struct {
    long    red, green, blue;
} RGBError;

OSErr ColourClut(Pixel **table)
{
    long    y, u, v, r, g, b, i;
    RGBError    *err;
    THz     saveZone;

    NewPointer(*table,Pixel*,Y_LEVELS*UV_LEVELS*UV_LEVELS*sizeof(long)); /* 64k ta
    NewPointer(err,RGBError*,Y_LEVELS*UV_LEVELS*UV_LEVELS*sizeof(RGBError));

    for(i=0;i<4;i++)
    for(y=-Y_LEVELS/2;y<Y_LEVELS/2;y++)
    for(u=-UV_LEVELS/2;u<UV_LEVELS/2;u++)
    for(v=-UV_LEVELS/2;v<UV_LEVELS/2;v++) {
        RGBColor    src, dst;
        long    index,in;

        index=((y&0x3F)<<8)|((u&0xF)<<4)|(v&0xF);

        r = 32768L + ((y<<9) + (1436L*u) <<2);
        g = 32768L + ((y<<9) - (731L*u) - (352L*v) <<2);
        b = 32768L + ((y<<9) + (1815L*v) <<2);

        if (i>0) {
            r-=err[index].red;
            g-=err[index].green;
            b-=err[index].blue;
        }

        src.red=r<0?0:r>65534?65534:r;
        src.green=g<0?0:g>65534?65534:g;
        src.blue=b<0?0:b>65534?65534:b;

        (*table)[index].rgb[i]=(unsigned char)Color2Index(&src);
```

Engineering:KlicsCode:CompPict:Clut.c

```
        Index2Color((*table)[index].rgb[i],&dst);
        err[index].red=dst.red-src.red;
        err[index].green=dst.green-src.green;
        err[index].blue=dst.blue-src.blue;
    }
    DisposePtr((Ptr)err);
    return(noErr);
}

typedef struct {
    short   pel[2];
} Pix16;

typedef struct {
    unsigned char   pel[4];
} Pix8;

#define YS  64
#define UVS 32

OSErr Colour8(Pix8 **table)
{
    long    y, u, v, r, g, b, i;
    RGBError    *err;
    THz     saveZone;

    NewPointer(*table,Pix8*,YS*UVS*UVS*sizeof(Pix8)); /* 128k table */
    NewPointer(err,RGBError*,YS*UVS*UVS*sizeof(RGBError));

    for(i=0;i<4;i++)
    for(y=-YS/2;y<YS/2;y++)
    for(u=-UVS/2;u<UVS/2;u++)
    for(v=-UVS/2;v<UVS/2;v++) {
        RGBColor    src, dst;
        long    index;

        index=(y<<10)|((u&0x1F)<<5)|(v&0x1F);

        r = 32768L + ((y<<10) + (1436L*u) <<1);
        g = 32768L + ((y<<10) - (731L*u) - (352L*v) <<1);
        b = 32768L + ((y<<10) + (1815L*v) <<1);

        if (i>0) {
            r-=err[32768+index].red;
            g-=err[32768+index].green;
            b-=err[32768+index].blue;
        }

        src.red=r<0?0:r>65534?65534:r;
        src.green=g<0?0:g>65534?65534:g;
        src.blue=b<0?0:b>65534?65534:b;

        (*table)[32768+index].pel[i]=(unsigned char)Color2Index(&src);
        Index2Color((*table)[32768+index].pel[i],&dst);

        err[32768+index].red=dst.red-src.red;
        err[32768+index].green=dst.green-src.green;
        err[32768+index].blue=dst.blue-src.blue;
    }
    DisposePtr((Ptr)err);
    return(noErr);
}
```

Engineering:KlicsCode:CompPict:Clut.c

```
OSErr Colour16(Pix16 **table)
{
    long    y, u, v, r, g, b, i;
    RGBError    *err;
    THz     saveZone;

    NewPointer(*table,Pix16*,YS*UVS*UVS*sizeof(Pix16)); /* 128k table */
    NewPointer(err,RGBError*,YS*UVS*UVS*sizeof(RGBError));

    for(i=0;i<2;i++)
    for(y=-YS/2;y<YS/2;y++)
    for(u=-UVS/2;u<UVS/2;u++)
    for(v=-UVS/2;v<UVS/2;v++) {
        RGBColor    src, dst;
        long    index;

        index=(y<<10)|((u&0x1F)<<5)|(v&0x1F);

        r = 32768L + ((y<<10) + (1436L*u) <<1);
        g = 32768L + ((y<<10) - (731L*u) - (352L*v) <<1);
        b = 32768L + ((y<<10) + (1815L*v) <<1);

        if (i>0) {
            r-=err[32768+index].red;
            g-=err[32768+index].green;
            b-=err[32768+index].blue;
        }

        src.red=r<0?0:r>65534?65534:r;
        src.green=g<0?0:g>65534?65534:g;
        src.blue=b<0?0:b>65534?65534:b;

        dst.red= src.red&0xF800;
        dst.green= src.green&0xF800;
        dst.blue= src.blue&0xF800;

        (*table)[32768+index].pel[i]=(dst.red>>1)|(dst.green>>6)|(dst.blue>>11);

        err[32768+index].red=dst.red-src.red;
        err[32768+index].green=dst.green-src.green;
        err[32768+index].blue=dst.blue-src.blue;
    }
    DisposePtr((Ptr)err);
    return(noErr);
}

Boolean
GreyClut(CTabHandle clut)
{
    Boolean result=true;
    int     i, size;

    size=(*clut)->ctSize;
    for(i=0;i<=size && result;i++) {
        int     r,g,b;

        r=(*clut)->ctTable[i].rgb.red;
        g=(*clut)->ctTable[i].rgb.green;
        b=(*clut)->ctTable[i].rgb.blue;

        result=(r==g && g==b);
    }
```

```
return result;
}
```

Engineering:KlicsCode:CompPict:Bits3.h

```
/******************************************************
 *
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 *
 * Written by: Adrian Lewis
 *
 ******************************************************/
/*
    Bits3.h: fast bit read/write definitions

    buf_use     define static variables
    buf_winit   initialise vars for write
    buf_rinit   initialise vars for read
    buf_set     set current bit
    buf_get     get current bit
    buf_winc    increment write buffer
    buf_rinc    increment read buffer
    buf_size    fullness of buffer in bytes
    buf_flush   flush buffer

    User defined macro/function buf_over must be defined in case of buffer overflo
*/

typedef struct {
    unsigned long   *buf;
    union   {
        unsigned long   mask;
        long    bno;
    } index;
    unsigned long   *ptr, data, size;
} Buffer, *Buf;

#define buf_winit(buf) \
    buf->index.mask=0x80000000; \
    buf->ptr=&buf->buf[0]; \
    buf->data=0;

#define buf_rinit(buf) \
    buf->index.bno=0; \
    buf->ptr=&buf->buf[0];

#define buf_set(buf) \
    buf->data |= buf->index.mask;

#define buf_get(buf) \
    0!=(buf->data & (1<<buf->index.bno) )

#define buf_winc(buf) \
    if (buf->index.mask==1) { \
        *buf->ptr=buf->data; \
        buf->data=0; \
        buf->index.mask=0x80000000; \
        buf->ptr++; \
    } else buf->index.mask >>= 1;

#define buf_rinc(buf) \
    if (--(buf->index.bno)<0) { \
        buf->data=*buf->ptr++; \
        buf->index.bno=31; \
    };

/* buf_size only valid after buf_flush */
```

Engineering:KlicsCode:CompPict:Bits3.h

```
#define buf_size(buf) \
    (unsigned char *)buf->ptr-(unsigned char *)&buf->buf[0]

#define buf_flush(buf) \
    if (buf->index.mask!=0x80000000) { \
        buf->data|=buf->index.mask-1; \
        *buf->ptr=buf->data; \
        buf->ptr++; \
    }
```

Engineering:KlicsCode:CompPict:Bits3.a

```
*--------------------------------
*
*   © Copyright 1993 KLICS Limited
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*
*   Written by: Adrian Lewis
*
*--------------------------------
*
*   68000 Bit buffer code (Bits2.h)
*
*--------------------------------
*
*   Macros:
*       buf_winit   &ptr,&data,&mask,&buf
*       buf_rinit   &ptr,&bno,&buf
*       buf_set     &data,&mask
*       buf_get     &data,&bno
*       buf_winc    &ptr,&data,&mask
*       buf_rinc    &ptr,&data,&index
*       buf_flush   &ptr,&data,&mask
*
*--------------------------------
        macro
        buf_winit   &ptr,&data,&mask,&buf
*
        move.l      #$80000000,&mask        ; mask=100..
        move.l      &buf,&ptr               ; ptr=buf
        clr.l       &data                   ; data=0
*
        endm
*--------------------------------
        macro
        buf_rinit   &ptr,&bno,&buf
*
        clr.b       &bno                    ; bno=0
        move.l      &buf,&ptr               ; ptr=buf
*
        endm
*--------------------------------
        macro
        buf_set     &data,&mask
*
        or.l        &mask,&data             ; data |= mask
*
        endm
*--------------------------------
        macro
        buf_get     &data,&bno
*
        subq.b      #1,&bno
        btst        &bno,&data
*
        endm
*--------------------------------
        macro
        buf_winc    &ptr,&data,&mask
*
        lsr.l       #1,&mask                ; mask>>=1
        bne.s       @cont                   ; if non-zero continue
        move.l      &data,(&ptr)+           ; *ptr++=data
        clr.l       &data                   ; data=0
        move.l      #$80000000,&mask        ; mask=100...
```

Engineering:KlicsCode:CompPict:Bits3.a

```
@cont
*
        endm
*-----------------------------------
        macro
        buf_rinc    &ptr,&data,&bno
*
        cmpi.b      #16,&bno
        bge.s       @cont
        swap        &data
        move.w      (&ptr)+,&data           ; data=*ptr++
        add.b       #16,&bno                ; bno+=16
@cont
*
        endm
*-----------------------------------
        macro
        buf_flush   &ptr,&data,&mask
*
        cmp.l       #$80000000,&mask        ; mask-8000000?
        beq.s       @cont                   ; if buffer empty continue
        move.l      &data,(&ptr)+           ; *ptr++=data
*
        endm
*-----------------------------------
```

Engineering:KlicsCode:CompPict:Backward.c

```
/*******************************
 *
 * © Copyright 1993 KLICS Limited
 * All rights reserved.
 *
 * Written by: Adrian Lewis
 *
 *******************************/
/*
    Extra fast Backward\convolver
    New wavelet coeffs : 3 5 1 1, 1 2 1, 1 1

    Optimized for speed:
        dirn - False
        src/dst octave == 0
*/

#define BwdS0(addr0,dAG,dAH,dBH) \
    v=*(short *)addr0; \
    dAG= -v; \
    dAH= v; \
    dBH= v<<1; \

#define BwdS1(addr1,addr0,dAG,dAH,dBH) \
    v=*(short *)addr1; \
    dBH+= v>>1; \
    dAG+= v+(vs=v<<1); \
    dAH-= v+(vs<<=1); \
    *(short *)addr0=dBH>>1;

#define Bwd2(addr2,dAG,dAH,dBG,dBH) \
    v=*(short *)addr2; \
    dBG= -v; \
    dBH= v; \
    dAH+= v+(vs=v<<1); \
    dAG+= v+(vs<<=1);

#define Bwd3(addr3,addr2,addr1,dAG,dAH,dBG,dBH) \
    v=*(short *)addr3; \
    dAH+= v; \
    dAG+= v; \
    dBG+= v+(vs=v<<1); \
    dBH-= v+(vs<<=1); \
    *(short *)addr1=(dAH+1)>>2; \
    *(short *)addr2=(dAG+1)>>2;

#define Bwd0(addr0,dAG,dAH,dBG,dBH) \
    v=*(short *)addr0; \
    dAG= -v; \
    dAH= v; \
    dBH+= v+(vs=v<<1); \
    dBG+= v+(vs<<=1);

#define Bwd1(addr1,addr0,addr3,dAG,dAH,dBG,dBH) \
    v=*(short *)addr1; \
    dBH+= v; \
    dBG+= v; \
    dAG+= v+(vs=v<<1); \
    dAH-= v+(vs<<=1); \
    *(short *)addr3=(dBH+1)>>2; \
    *(short *)addr0=(dBG+1)>>2;

#define BwdE2(addr2,dAG,dAH,dBH) \
```

```
    v=*(short *)addr2; \
    dBH=  vs=v<<1; \
    dAH+= v+(vs=v<<1); \
    dAG+= v+(vs<<=1);

#define BwdE3(addr3,addr2,addr1,dAG,dAH,dBH) \
    v=*(short *)addr3; \
    dAH+= v; \
    dAG+= v; \
    dBH-= v+(vs=v<<1); \
    dBH-= v+(vs<<=1); \
    *(short *)addr1=(dAH+1)>>2; \
    *(short *)addr2=(dAG+1)>>2; \
    *(short *)addr3=dBH>>1;

#define Bwd(base,end,inc) \
    addr0=base; \
    addr3=addr0-(inc>>2); \
    addr2=addr3-(inc>>2); \
    addr1=addr2-(inc>>2); \
    BwdS0(addr0,dAG,dAH,dBH); \
    addr1+=inc; \
    BwdS1(addr1,addr0,dAG,dAH,dBH); \
    addr2+=inc; \
    while(addr2<end) { \
        Bwd2(addr2,dAG,dAH,dBG,dBH); \
        addr3+=inc; \
        Bwd3(addr3,addr2,addr1,dAG,dAH,dBG,dBH); \
        addr0+=inc; \
        Bwd0(addr0,dAG,dAH,dBG,dBH); \
        addr1+=inc; \
        Bwd1(addr1,addr0,addr3,dAG,dAH,dBG,dBH); \
        addr2+=inc; \
    } \
    BwdE2(addr2,dAG,dAH,dBH); \
    addr3+=inc; \
    BwdE3(addr3,addr2,addr1,dAG,dAH,dBH);

#define BwdS0r2(addr0,dAG,dAH,dBH) \
    v=*(short *)addr0; \
    dAG= 0; \
    dAH= v; \
    dBH= v; \

#define BwdS1r2(addr1,addr0,dAG,dAH,dBH) \
    v=*(short *)addr1; \
    dBH+= v>>2; \
    dAG+= v; \
    dAH-= v<<1; \
    *(short *)addr0=dBH;

#define Bwd2r2(addr2,dAG,dAH,dBG,dBH) \
    v=*(short *)addr2; \
    dBG=  0; \
    dBH=  v; \
    dAH+= v; \
    dAG+= v<<1;

#define Bwd3r2(addr3,addr2,addr1,dAG,dAH,dBG,dBH) \
    v=*(short *)addr3; \
    dAH+= 0; \
    dAG+= v; \
    dBG+= v; \
```

```
    dBH-= v<<1; \
    *(short *)addr1=dAH>>1; \
    *(short *)addr2=dAG>>1;

#define Bwd0r2(addr0,dAG,dAH,dBG,dBH) \
    v=*(short *)addr0; \
    dAG=  0; \
    dAH=  v; \
    dBH+= v; \
    dBG+= v<<1;

#define Bwd1r2(addr1,addr0,addr3,dAG,dAH,dBG,dBH) \
    v=*(short *)addr1; \
    dBH+= 0; \
    dBG+= v; \
    dAG+= v; \
    dAH-= v<<1; \
    *(short *)addr3=dBH>>1; \
    *(short *)addr0=dBG>>1;

#define BwdE2r2(addr2,dAG,dAH,dBH) \
    v=*(short *)addr2; \
    dBH=  v; \
    dAH+= v; \
    dAG+= v<<1;

#define BwdE3r2(addr3,addr2,addr1,dAG,dAH,dBH) \
    v=*(short *)addr3; \
    dAH+= 0; \
    dAG+= v; \
    dBH-= v; \
    dBH-= v<<1; \
    *(short *)addr1=dAH>>1; \
    *(short *)addr2=dAG>>1; \
    *(short *)addr3=dBH;

#define Bwdr2(base,end,inc) \
    addr0=base; \
    addr3=addr0-(inc>>2); \
    addr2=addr3-(inc>>2); \
    addr1=addr2-(inc>>2); \
    BwdS0r2(addr0,dAG,dAH,dBH); \
    addr1+=inc; \
    BwdS1r2(addr1,addr0,dAG,dAH,dBH); \
    addr2+=inc; \
    while(addr2<end) { \
        Bwd2r2(addr2,dAG,dAH,dBG,dBH); \
        addr3+=inc; \
        Bwd3r2(addr3,addr2,addr1,dAG,dAH,dBG,dBH); \
        addr0+=inc; \
        Bwd0r2(addr0,dAG,dAH,dBG,dBH); \
        addr1+=inc; \
        Bwd1r2(addr1,addr0,addr3,dAG,dAH,dBG,dBH); \
        addr2+=inc; \
    } \
    BwdE2r2(addr2,dAG,dAH,dBH); \
    addr3+=inc; \
    BwdE3r2(addr3,addr2,addr1,dAG,dAH,dBH);

#define BwdS0r3(addr0,dAG,dAH,dBH) \
    v=*(short *)addr0; \
    dAG= 0; \
    dAH= 0; \
```

```
    dBH= v>>1; \

#define BwdS1r3(addr1,addr0,dAG,dAH,dBH) \
    v=*(short *)addr1; \
    dBH+= v>>1; \
    dAG+= v; \
    dAH-= v; \
    *(short *)addr0=dBH<<1;

#define Bwd2r3(addr2,dAG,dAH,dBG,dBH) \
    v=*(short *)addr2; \
    dBG=  0; \
    dBH=  0; \
    dAH+= v; \
    dAG+= v;

#define Bwd3r3(addr3,addr2,addr1,dAG,dAH,dBG,dBH) \
    v=*(short *)addr3; \
    dAH+= 0; \
    dAG+= 0; \
    dBG+= v; \
    dBH-= v; \
    *(short *)addr1=dAH; \
    *(short *)addr2=dAG;

#define Bwd0r3(addr0,dAG,dAH,dBG,dBH) \
    v=*(short *)addr0; \
    dAG=  0; \
    dAH=  0; \
    dBH+= v; \
    dBG+= v;

#define Bwd1r3(addr1,addr0,addr3,dAG,dAH,dBG,dBH) \
    v=*(short *)addr1; \
    dBH+= 0; \
    dBG+= 0; \
    dAG+= v; \
    dAH-= v; \
    *(short *)addr3=dBH; \
    *(short *)addr0=dBG;

#define BwdE2r3(addr2,dAG,dAH,dBH) \
    v=*(short *)addr2; \
    dBH=  v>>1; \
    dAH+= v; \
    dAG+= v;

#define BwdE3r3(addr3,addr2,addr1,dAG,dAH,dBH) \
    v=*(short *)addr3; \
    dAH+= 0; \
    dAG+= 0; \
    dBH-= v; \
    dBH-= v; \
    *(short *)addr1=dAH; \
    *(short *)addr2=dAG; \
    *(short *)addr3=dBH<<1;

#define Bwdr3(base,end,inc) \
    addr0=base; \
    addr3=addr0-(inc>>2); \
    addr2=addr3-(inc>>2); \
    addr1=addr2-(inc>>2); \
    BwdS0r3(addr0,dAG,dAH,dBH); \
```

Engineering:KlicsCode:CompPict:Backward.c

```
    addr1+=inc; \
    BwdS1r3(addr1,addr0,dAG,dAH,dBH); \
    addr2+=inc; \
    while(addr2<end) { \
        Bwd2r3(addr2,dAG,dAH,dBG,dBH); \
        addr3+=inc; \
        Bwd3r3(addr3,addr2,addr1,dAG,dAH,dBG,dBH); \
        addr0+=inc; \
        Bwd0r3(addr0,dAG,dAH,dBG,dBH); \
        addr1+=inc; \
        Bwd1r3(addr1,addr0,addr3,dAG,dAH,dBG,dBH); \
        addr2+=inc; \
    } \
    BwdE2r3(addr2,dAG,dAH,dBH); \
    addr3+=inc; \
    BwdE3r3(addr3,addr2,addr1,dAG,dAH,dBH);

extern void FASTBACKWARD(char *data, long inc1, long loop1, long inc2, char *end2)
extern void HAARBACKWARD(char *data, long inc1, long loop1, long inc2, long loop2)
extern void HAARTOPBWD(char *data,long height,long width);
/* extern void  HAARXTOPBWD(char *data,long area);*/

void    FasterBackward(char *data, long inc1, long end1, long inc2, char *end2)
{
    register short  v, vs, v3, dAG, dAH, dBG, dBH, inc;
    register char   *addr0, *addr1, *addr2, *addr3, *end;
    char    *base;

    inc=inc1;
    for(base=data;base<end2;base+=inc2) {
        end=base+end1;
        Bwd(base,end,inc);
    }
}

extern  void    TOPBWD(char *data, char *dst, long size_1, long size_0);

void    TestTopBackward(short *data,int size[2],int oct_src)
{
    int     oct, area=size[0]*size[1]<<1;
    short   width=size[0]<<1;
    char    *top=area+(char *)data, *left=width+(char *)data;

    for(oct=oct_src-1;oct>0;oct--) {
        long    cinc=2<<oct, cinc4=cinc<<2,
                rinc=size[0]<<oct+1, rinc4=rinc<<2; /* col and row increments in t

        FASTBACKWARD((char *)data,rinc4,area-(rinc<<1),cinc,left);
        FASTBACKWARD((char *)data,cinc4,width-(cinc<<1),rinc,top);
    }
/*  FasterBackward((char *)data,size[0]<<3,area-(size[0]<<2),2,left);
    FasterBackward((char *)data,8,width-4,size[0]<<1,top);*/
    TOPBWD((char *)data,(char *)data,size[0],size[1]);
}
void    TestBackward(data,size,oct_src)

short   *data;
int     size[2], oct_src;

{
    int     oct, area=size[0]*size[1]<<1;
    short   width=size[0]<<1;
    char    *top=area+(char *)data, *left=width+(char *)data;
```

```
    for(oct=oct_src-1;oct>=0;oct--) {
        long    cinc=2<<oct, cinc4=cinc<<2,
                rinc=size[0]<<oct+1, rinc4=rinc<<2; /* col and row increments in t

        FasterBackward((char *)data,rinc4,area-(rinc<<1),cinc,left);
        FasterBackward((char *)data,cinc4,width-(cinc<<1),rinc,top);
    }
}

void    Backward3511(data,size,oct_src)

short   *data;
int     size[2], oct_src;

{
    int     oct, area=size[0]*size[1]<<1;
    short   width=size[0]<<1;
    char    *top=area+(char *)data, *left=width+(char *)data;

    for(oct=oct_src-1;oct>0;oct--) {
        long    cinc=2<<oct, cinc4=cinc<<2,
                rinc=size[0]<<oct+1, rinc4=rinc<<2; /* col and row increments in t


        BACK3511((char *)data,rinc4,area-(rinc<<1),cinc,left);
        BACK3511((char *)data,cinc4,width-(cinc<<1),rinc,top);
    }
    BACK3511V((char *)data,size[0]<<3,area-(size[0]<<2),4,left);
    BACK3511H((char *)data,8,width-4,size[0]<<1,top);
/*  TOPBWD((char *)data,(char *)data,size[1],size[0]);*/
}
```

Engineering:KlicsCode:CompPict:Backward.a

```
*-------------------------------
*
*    © Copyright 1993 KLICS Limited
*    All rights reserved.
*
*    Written by: Adrian Lewis
*
*-------------------------------
*
*    680X0 3511 Backward code
*
*    Coeffs 11 19 5 3
*    become  3  5 1 1
*
*-------------------------------
        seg         'klics'
*-------------------------------
        macro
        BwdStart0   &addr0,&dAG,&dAH,&dBH
*
        move.w      (&addr0),&dAH     ; dAH=*(short *)addr0
        move.w      &dAH,&dAG         ; dAG=v
        neg.w       &dAG              ; dAG= -dAG
        move.w      &dAH,&dBH         ; dBH=v
        add.w       &dBH,&dBH         ; dBH=v<<1
*
        endm
*-------------------------------
        macro
        BwdStart1   &addr1,&addr0,&dAG,&dAH,&dBH
*
        move.w      (&addr1),d0       ; v=*(short *)addr1
        move.w      d0,d1             ; vs=v
        asr.w       #1,d1             ; vs=v>>1
        add.w       d1,&dBH           ; dBH+= v>>1
        add.w       d0,&dAG           ; dAG+=v
        sub.w       d0,&dAH           ; dAH-=v
        add.w       d0,d0             ; v<<=1
        add.w       d0,&dAG           ; dAG-=2v
        add.w       d0,d0             ; v<<=1
        sub.w       d0,&dAH           ; dAH-=4v
        asr.w       #1,&dBH           ; dBH>>=1
        move.w      &dBH,(&addr0)     ; *(short *)addr0=dBH
*
        endm
*-------------------------------
        macro
        BwdEven &addr2,&dAG,&dAH,&dBG,&dBH
*
        move.w      (&addr2),d0       ; v=*(short *)addr2
        move.w      d0,&dBH           ; dBH=v
        move.w      d0,&dBG           ; dBG=v
        neg.w       &dBG              ; dBG=-v
        add.w       d0,&dAH           ; dAH+=v
        add.w       d0,&dAG           ; dAG+=v
        add.w       d0,d0             ; 2v
        add.w       d0,&dAH           ; dAH+=v
        add.w       d0,d0             ; 2v
        add.w       d0,&dAG           ; dAH+=v
*
        endm
*-------------------------------
        macro
```

Engineering:KlicsCode:CompPict:Backward.a

```
        BwdOdd          &addr3,&addr2,&addr1,&dAG,&dAH,&dBG,&dBH

        move.w          (&addr3),d0          ; v=*(short *)addr3

        add.w           d0,&dAH              ; dAH+=v
        add.w           d0,&dAG              ; dAG+=v
        add.w           d0,&dBG              ; dBG+=v
        sub.w           d0,&dBH              ; dBH-=v
        add.w           d0,d0                ; 2v
        add.w           d0,&dBG              ; dBG+=v
        add.w           d0,d0                ; 4v
        sub.w           d0,&dBH              ; dBH-=4v

        asr.w           #2,&dAH              ; dAH>>=2
        move.w          &dAH,(&addr1)        ; *(short *)addr1=dAH
        asr.w           #2,&dAG              ; dAG>>=2
        move.w          &dAG,(&addr2)        ; *(short *)addr2=dAG

        endm
*--------------------------------------
        macro
        BwdEnd2         &addr2,&dAG,&dAH,&dBH

        move.w          (&addr2),d0          ; v=*(short *)addr2

        add.w           d0,&dAH              ; dAH+=v
        add.w           d0,&dAG              ; dAG+=v
        add.w           d0,d0                ; 2v
        move.w          d0,&dBH              ; dBH=2v
        add.w           d0,&dAH              ; dAH+=2v
        add.w           d0,d0                ; 4v
        add.w           d0,&dAG              ; dAG+=4v

        endm
*--------------------------------------
        macro
        BwdEnd3         &addr3,&addr2,&addr1,&dAG,&dAH,&dBH

        move.w          (&addr3),d0          ; v=*(short *)addr3
        add.w           d0,&dAH              ; dAH+=v
        add.w           d0,&dAG              ; dAG+=v
        lsl.w           #3,d0                ; 8v
        sub.w           d0,&dBH              ; dBH-=8v
        asr.w           #2,&dAH              ; dAH>>=2
        move.w          &dAH,(&addr1)        ; *(short *)addr1=dAH
        asr.w           #2,&dAG              ; dAG>>=2
        move.w          &dAG,(&addr2)        ; *(short *)addr2=dAG
        asr.w           #1,&dBH              ; dBH>>=1
        move.w          &dBH,(&addr3)        ; *(short *)addr3=dBH

        endm
*--------------------------------------
        macro
        Bwd             &base,&end,&inc

        movea.l         &base,a0                     ; addr0=base
        move.l          &inc,d0                      ; d0=inc
        asr.l           #2,d0                        ; d0=inc>>2
        movea.l         a0,a3                        ; addr3=addr0
        suba.l          d0,a3                        ; addr3-=(inc>>2)
        movea.l         a3,a2                        ; addr2=addr3
        suba.l          d0,a2                        ; addr2-=(inc>>2)
        movea.l         a2,a1                        ; addr1=addr2
```

Engineering:KlicsCode:CompPict:Backward.a

```
        suba.l      d0.a1                   ; addr1-=(inc>>2)
        BwdStart0   a0,d4,d5,d7             ; BwdStart0(addr0,dAG,dAH,dBH)
        adda.l      &inc,a1                 ; addr1+=inc
        BwdStart1   a1,a0,d4,d5,d7          ; BwdStart1(addr1,addr0,dAG,dAH,dBH)
        adda.l      &inc,a2                 ; addr2+=inc
@do     BwdEven     a2,d4,d5,d6,d7          ; BwdEven(addr2,dAG,dAH,dBG,dBH)
        adda.l      &inc,a3                 ; addr3+=inc
        BwdOdd      a3,a2,a1,d4,d5,d6,d7    ; BwdOdd(addr3,addr2,addr1,dAG,dAH,dBG
        adda.l      &inc.a0                 ; addr0+=inc
        BwdEven     a0,d6,d7,d4,d5          ; BwdEven(addr0,dBG,dBH,dAG,dAH)
        adda.l      &inc,a1                 ; addr1+=inc
        BwdOdd      a1,a0,a3,d6,d7,d4,d5    ; BwdOdd(addr1,addr0,addr3,dBG,dBH,dAG
        adda.l      &inc,a2                 ; addr2+=inc
        cmpa.l      a2,&end                 ; addr2<end
        bgt.s       @do                     ; while
        BwdEnd2     a2,d4,d5,d7             ; BwdEnd2(addr2,dAG,dAH,dBH)
        adda.l      &inc,a3                 ; addr3+=inc
        BwdEnd3     a3,a2,a1,d4,d5,d7       ; BwdEnd3(addr3,addr2,addr1,dAG,dAH,dB
*
        endm
*---------------------------------
Back3511    FUNC    EXPORT
*
PS      RECORD      8
data    DS.L        1
inc1    DS.L        1
end1    DS.L        1
inc2    DS.L        1
end2    DS.L        1
        ENDR
*
        link        a6,#0                   ; no local variables
        movem.l     d4-d7/a3-a5,-(a7)       ; store registers
*
        move.l      PS.inc1(a6),d3          ; inc=inc1
        movea.l     PS.data(a6),a5          ; base=data
@do     movea.l     a5,a4                   ; end=base
        adda.l      PS.end1(a6),a4          ; end+=end1
        Bwd         a5,a4,d3                ; Bwd(base,end,inc)
        adda.l      PS.inc2(a6),a5          ; base+=inc2
        cmpa.l      PS.end2(a6),a5          ; end2>base
        blt.w       @do                     ; for
*
        movem.l     (a7)+,d4-d7/a3-a5       ; restore registers
        unlk        a6                      ; remove locals
        rts                                 ; return
*
        ENDFUNC
*---------------------------------
        macro
        BwdStartV0  &addr0,&dAG,&dAH,&dBH
*
        move.l      (&addr0),&dAH   ; dAH=*(short *)addr0
        move.l      &dAH,&dAG       ; dAG=v
        neg.l       &dAG            ; dAG= -dAG
        move.l      &dAH,&dBH       ; dBH=v
        add.l       &dBH,&dBH       ; dBH=v<<1
*
        endm
*---------------------------------
        macro
        BwdStartV1  &addr1,&addr0,&dAG,&dAH,&dBH
*
```

```
        move.l      (&addr1).d0         ; v=*(short *)addr1
        move.l      d0,d1               ; vs=v
        asr.l       #1,d1               ; vs=v>>1
        add.l       d1,&dBH             ; dBH+= v>>1
        add.l       d0,&dAG             ; dAG+=v
        sub.l       d0,&dAH             ; dAH-=v
        add.l       d0,d0               ; v<<=1
        add.l       d0,&dAG             ; dAG+=2v
        add.l       d0,d0               ; v<<=1
        sub.l       d0,&dAH             ; dAH-=4v

        asr.l       #1,&dBH             ; dBH>>=1
        add.w       &dBH,&dBH           ; shift word back
        asr.w       #1,&dBH             ; dBH>>=1
        move.l      &dBH,(&addr0)       ; *(short *)addr0=dBH
*
        endm
*-----------------------------------
        macro
        BwdEvenV    &addr2,&dAG,&dAH,&dBG,&dBH
*
        move.l      (&addr2),d0         ; v=*(short *)addr2
        move.l      d0,&dBH             ; dBH=v
        move.l      d0,&dBG             ; dBG=v
        neg.l       &dBG                ; dBG=-v
        add.l       d0,&dAH             ; dAH+=v
        add.l       d0,&dAG             ; dAG+=v
        add.l       d0,d0               ; 2v
        add.l       d0,&dAH             ; dAH+=v
        add.l       d0,d0               ; 2v
        add.l       d0,&dAG             ; dAH+=v
*
        endm
*-----------------------------------
        macro
        BwdOddV     &addr3,&addr2,&addr1,&dAG,&dAH,&dBG,&dBH
*
        move.l      (&addr3).d0         ; v=*(short *)addr3

        add.l       d0,&dAH             ; dAH+=v
        add.l       d0,&dAG             ; dAG+=v
        add.l       d0,&dBG             ; dBG+=v
        sub.l       d0,&dBH             ; dBH-=v
        add.l       d0,d0               ; 2v
        add.l       d0,&dBG             ; dBG+=v
        add.l       d0,d0               ; 4v
        sub.l       d0,&dBH             ; dBH-=4v

        asr.l       #2,&dAH             ; dAH>>=2
        lsl.w       #2,&dAH             ; shift word back
        asr.w       #2,&dAH             ; dAH>>=2
        move.l      &dAH,(&addr1)       ; *(short *)addr1=dAH
        asr.l       #2,&dAG             ; dAG>>=2
        lsl.w       #2,&dAG             ; shift word back
        asr.w       #2,&dAG             ; dAG>>=2
        move.l      &dAG,(&addr2)       ; *(short *)addr2=dAG
*
        endm
*-----------------------------------
        macro
        BwdEndV2    &addr2,&dAG,&dAH,&dBH
*
        move.l      (&addr2),d0         ; v=*(short *)addr2
```

Engineering:KlicsCode:CompPict:Backward.a

```
        add.l       d0,&dAH             ; dAH+=v
        add.l       d0,&dAG             ; dAG+=v
        add.l       d0,d0               ; 2v
        move.l      d0,&dBH             ; dBH=2v
        add.l       d0,&dAH             ; dAH+=2v
        add.l       d0,d0               ; 4v
        add.l       d0,&dAG             ; dAG+=4v
*
        endm
*--------------------------------
        macro
        BwdEndV3    &addr3,&addr2,&addr1,&dAG,&dAH,&dBH
*
        move.l      (&addr3),d0         ; v=*(short *)addr3
        add.l       d0,&dAH             ; dAH+=v
        add.l       d0,&dAG             ; dAG+=v
        lsl.l       #3,d0               ; 8v
        sub.l       d0,&dBH             ; dBH-=8v
        asr.l       #2,&dAH             ; dAH>>=2
        lsl.w       #2,&dAH             ; shift word back
        asr.w       #2,&dAH             ; dAH>>=2
        move.l      &dAH,(&addr1)       ; *(short *)addr1=dAH
        asr.l       #2,&dAG             ; dAG>>=2
        lsl.w       #2,&dAG             ; shift word back
        asr.w       #2,&dAG             ; dAG>>=2
        move.l      &dAG,(&addr2)       ; *(short *)addr2=dAG
        asr.l       #1,&dBH             ; dBH>>=1
        lsl.w       #1,&dBH             ; shift word back
        asr.w       #1,&dBH             ; dAH>>=2
*       add.l       &dBH,&dBH           ; dBH<<=1
        move.l      &dBH,(&addr3)       ; *(short *)addr3=dBH
*
        endm
*--------------------------------
        macro
        BwdV        &base,&end,&inc
*
        movea.l     &base,a0                    ; addr0=base
        move.l      &inc,d0                     ; d0=inc
        asr.l       #2,d0                       ; d0=inc>>2
        movea.l     a0,a3                       ; addr3=addr0
        suba.l      d0,a3                       ; addr3-=(inc>>2)
        movea.l     a3,a2                       ; addr2=addr3
        suba.l      d0,a2                       ; addr2-=(inc>>2)
        movea.l     a2,a1                       ; addr1=addr2
        suba.l      d0,a1                       ; addr1-=(inc>>2)
        BwdStartV0  a0,d4,d5,d7                 ; BwdStart0(addr0,dAG,dAH,dBH)
        adda.l      &inc,a1                     ; addr1+=inc
        BwdStartV1  a1,a0,d4,d5,d7              ; BwdStart1(addr1,addr0,dAG,dAH,dBH)
        adda.l      &inc,a2                     ; addr2+=inc
@do     BwdEvenV    a2,d4,d5,d6,d7              ; BwdEven(addr2,dAG,dAH,dBG,dBH)
        adda.l      &inc,a3                     ; addr3+=inc
        BwdOddV     a3,a2,a1,d4,d5,d6,d7        ; BwdOdd(addr3,addr2,addr1,dAG,dAH,dBG
        adda.l      &inc,a0                     ; addr0+=inc
        BwdEvenV    a0,d6,d7,d4,d5              ; BwdEven(addr0,dBG,dBH,dAG,dAH)
        adda.l      &inc,a1                     ; addr1+=inc
        BwdOddV     a1,a0,a3,d6,d7,d4,d5        ; BwdOdd(addr1,addr0,addr3,dBG,dBH,dAG
        adda.l      &inc,a2                     ; addr2+=inc
        cmpa.l      a2,&end                     ; addr2<end
        bgt.s       @do                         ; while
        BwdEndV2    a2,d4,d5,d7                 ; BwdEnd2(addr2,dAG,dAH,dBH)
        adda.l      &inc,a3                     ; addr3+=inc
```

Engineering:KlicsCode:CompPict:Backward.a

```
        BwdEndV3    a3,a2,a1,d4,d5,d7        ; BwdEnd3(addr3,addr2,addr1,dAG,dAH,dB
*
        endm
*----------------------------------
Back3511V   FUNC    EXPORT
*
PS      RECORD      8
data    DS.L        1
incl    DS.L        1
end1    DS.L        1
inc2    DS.L        1
end2    DS.L        1
        ENDR
*
        link        a6,#0                    ; no local variables
        movem.l     d4-d7/a3-a5,-(a7)        ; store registers
*
        move.l      PS.incl(a6),d3           ; inc=incl
        movea.l     PS.data(a6),a5           ; base=data
@do     movea.l     a5,a4                    ; end=base
        adda.l      PS.end1(a6),a4           ; end+=end1
        BwdV        a5,a4,d3                 ; Bwd(base,end,inc)
        adda.l      PS.inc2(a6),a5           ; base+=inc2
        cmpa.l      PS.end2(a6),a5           ; end2>base
        blt.w       @do                      ; for
*
        movem.l     (a7)+,d4-d7/a3-a5        ; restore registers
        unlk        a6                       ; remove locals
        rts                                  ; return
*
        ENDFUNC
*----------------------------------
        macro
        BwdStartH   &addrR,&A,&C
*
        move.l      (&addrR)+,&A     ; 1H1G=*(long *)addrR
        move.l      &A,d0            ; A=1H1G, d0=1H1G
        move.l      &A,&C            ; A=1H1G, d0=1H1G, C=1H1G
        add.w       &A,d0            ; A=1H1G, d0=1H2G, C=1H1G
        add.w       d0,&A            ; A=1H3G, d0=1H2G, C=1H1G
        add.w       &A,d0            ; A=1H3G, d0=1H5G, C=1H1G
        swap        &A               ; A=3GH1, d0=1H5G, C=1H1G
        sub.l       d0,&A            ; A=AAAA, d0=1H5G, C=1H1G
*
        endm
*----------------------------------
        macro
        BwdCycleH   &addrR,&addrW,&A,&B,&C
*
        move.l      (&addrR)+,&B     ; 1H1G=*(long *)addrR
        move.l      &B,d0            ; B=1H1G, d0=1H1G
        add.l       d0,d0            ; B=1H1G, d0=2H2G
        move.l      d0,d1            ; B=1H1G, d0=2H2G, d1=2H2G
        add.l       &B,d0            ; B=1H1G, d0=3H3G, d1=2H2G
        add.l       d0,d1            ; B=1H1G, d0=3H3G, d1=5H5G
        move.l      &B,d2            ; B=1H1G, d0=3H3G, d1=5H5G, d2=1H1G
        move.w      d1,d2            ; B=1H1G, d0=3H3G, d1=5H5G, d2=1H5G
        move.w      &B,d1            ; B=1H1G, d0=3H3G, d1=5H1G, d2=1H5G
        move.w      d0,&B            ; B=1H3G, d0=3H3G, d1=5H1G, d2=1H5G
        move.w      d1,d0            ; B=1H3G, d0=3H1G, d1=5H1G, d2=1H5G
        swap        &B               ; B=3G1H, d0=3H1G, d1=5H1G, d2=1H5G
        swap        d0               ; B=3G1H, d0=1G3H, d1=5H1G, d2=1H5G
```

```
        sub.l       d2,&B               ; B=3G1H-1H5G
        add.l       d0,&A               ; A+=1H3G
        add.l       d1,&A               ; A+=5G1H

        asr.w       #2,&A               ; A0>>=2
        move.w      &A,&C               ; C complete
        asr.l       #2,&A               ; A1>>=2
        move.l      &C,(&addrW)+        ; *(long *)addrW=DD
        move.l      &A,&C               ; C=A1XX
*
        endm
*-----------------------------------
        macro
        BwdEndH     &addrR,&addrW,&A,&B,&C
*
        move.l      (&addrR)+,d0        ; 1H1G=*(long *)addrR
        move.w      d0,d2               ; d2=1G
        lsl.w       #2,d2               ; d2=4G
        neg.w       d2                  ; d2=-4G
        swap        d0                  ; d0=1G1H
        add.w       d0,d2               ; d2+=1H
        move.l      d0,d1               ; d0=1G1H, d1=1G1H
        add.w       d0,d1               ; d0=1G1H, d1=1G2H
        add.w       d1,d0               ; d0=1G3H, d1=1G2H
        add.w       d0,d1               ; d0=1G3H, d1=1G5H
        swap        d1                  ; d0=1G3H, d1=5H1G
        add.l       d0,&A               ; A+=1G3H
        add.l       d1,&A               ; A+=5H1G

        asr.w       #2,&A               ; A1>>=2
        move.w      &A,&C               ; C complete
        asr.l       #2,&A               ; A0>>=2
        move.l      &C,(&addrW)+        ; *(long *)addrW=C
        move.w      d2,&A               ; A=D1D2
        move.l      &A,(&addrW)+        ; *(long *)addrW=A
*
        endm
*-----------------------------------
        macro
        BwdH        &base,&end,&inc
*
        movea.l     &base,a0                    ; addrR=base
        movea.l     a0,a1                       ; addrW=addrR
        BwdStartH   a0,d3,d5                    ; BwdStart(addrR,A,DD)
@do     BwdCycleH   a0,a1,d3,d4,d5              ; BwdCycle(addrR,addrW,A,B,C)
        BwdCycleH   a0,a1,d4,d3,d5              ; BwdCycle(addrR,addrW,B,A,C)
        cmpa.l      a0,&end                     ; addr2<end
        bgt.s       @do                         ; while
        BwdEndH     a0,a1,d3,d4,d5              ; BwdEnd(addrR,addrW,A,B,DD)
*
        endm
*-----------------------------------
Back3511H   FUNC    EXPORT
*
PS          RECORD  8
data        DS.L    1
inc1        DS.L    1
end1        DS.L    1
inc2        DS.L    1
end2        DS.L    1
            ENDR
*
        link        a6,#0                       ; no local variables
```

```
        movem.l     d4-d7/a3-a5,-(a7)       ; store registers
*
        move.l      PS.inc1(a6),d3          ; inc=inc1
        movea.l     PS.data(a6),a5          ; base=data
@do     movea.l     a5,a4                   ; end=base
        adda.l      PS.end1(a6),a4          ; end+=end1
        BwdH        a5,a4,d3                ; Bwd(base,end,inc)
        adda.l      PS.inc2(a6),a5          ; base+=inc2
        cmpa.l      PS.end2(a6),a5          ; end2>base
        blt.w       @do                     ; for
*
        movem.l     (a7)+,d4-d7/a3-a5       ; restore registers
        unlk        a6                      ; remove locals
        rts                                 ; return
*
        ENDFUNC
*---------------------------------
        END
```

```
/*******************************
 *
 * © Copyright 1993 KLICS Limited
 * All rights reserved.
 *
 * Written by: Adrian Lewis
 *
 ******************************/
/*
 * Full still/video Knowles-Lewis Image KlicsEncode System utilising HVS propert:
 * and delta-tree coding
 *
 * Recoded and re-rationalised (Stand alone version)
 */

#include    <PixMath.h>
#include    "Bits3.h"
#include    "Klics.h"
#include    "KlicsHeader.h"
#include    "KlicsEncode.h"


#include    <Math.h>

/* If bool true the negate value */
#define negif(bool,value)   ((bool)?-(value):(value))
#define abs(value)          negif(value<0,value)

extern  void    HaarForward();
extern  void    Daub4Forward();

/* Use the bit level file macros (Bits2.h)
buf_use;*/

/* Huffman encode a block */
#define HuffEncLev(lev,buf) \
    HuffEncode(lev[0],buf); \
    HuffEncode(lev[1],buf); \
    HuffEncode(lev[2],buf); \
    HuffEncode(lev[3],buf);

/* Fixed length encode block of integers */
#define IntEncLev(lev,lpf_bits,buf) \
    IntEncode(lev[0],lpf_bits,buf); \
    IntEncode(lev[1],lpf_bits,buf); \
    IntEncode(lev[2],lpf_bits,buf); \
    IntEncode(lev[3],lpf_bits,buf);

/* Define write a zero */
#define Token0 \
    buf_winc(buf);

/* Define write a one */
#define Token1 \
    buf_set(buf); buf_winc(buf);

/* Write block for data and update memory */
#define DoXfer(addr,pro,lev,dst,mode,oct,nmode,buf) \
    HuffEncLev(lev,buf); \
    PutData(addr,pro,dst); \
    mode[oct]=oct==0?M_STOP:nmode;

/*  Function Name:  Quantize
```

```
 * Description:    H.261 style quantizer
 * Arguments:  new, old - image blocks
 *             pro, lev - returned values
 *             q - quantizing divisor
 * Returns:    lev is all zero, quantized data (pro) & level (lev)
 */

Boolean Quantize(int new[4], int old[4], int pro[4], int lev[4], short q)
{
    int     blk, half_q=(1<<q)-1>>1;

    for(blk=0;blk<4;blk++) {
        int     data=new[blk]-old[blk],
                mag_level=abs(data)>>q;

        mag_level=mag_level>135?135:mag_level;
        lev[blk]=negif(data<0,mag_level);
        pro[blk]=old[blk]+negif(data<0,(mag_level<<q)+(mag_level!=0?half_q:0));
    }
    return(pro[0]==0 && pro[1]==0 && pro[2]==0 && pro[3]==0);
}

void    QuantizeLPF(int new[4],int pro[4],int lev[4],short q)
{
    int     blk, half_q=(1<<q)-1>>1;

    for(blk=0;blk<4;blk++) {
        int     data=new[blk],
                mag_level=abs(data)>>q;

        lev[blk]=negif(data<0,mag_level);
        pro[blk]=(lev[blk]<<q)+half_q;
    }
}

/*  Function Name:  GuessQuantize
 *  Description:    Estimate threshold quantiser value
 *  Arguments:  new, old - image blocks
 *              q - q weighting factor
 *  Returns:    estimated q_const
 */

float   GuessQuantize(int new[4],int old[4],float q)
{
    int     blk;
    float   qt_max=0.0;

    for(blk=0;blk<4;blk++) {
        int     i, data=abs(new[blk]-old[blk]);
        float   qt;

        for(i=0;data!=0;i++) data>>=1;
        if (i>0) i--;
        qt=(((3<<i)-1)>>1)/q;

        qt_max=qt_max>qt?qt_max:qt;
    }
    return(qt_max);
}

/*  Function Name:  IntEncode
 *  Description:    Write a integer to bit file
 *  Arguments:  lev - integer to write now signed
```

```
 *              bits - no of bits
 */

void    IntEncode(int lev,int bits,Buf buf)
{
/* Old version
    int     i;

    for(i=bits-1;i>=0;i--) {
        if (lev&(1<<i)) buf_set(buf);
        buf_winc(buf);
    }
*/
/* New version
    int     i, mag=abs(lev);
    Boolean sign=lev<0;

    if (1<<bits-1 <= mag) mag=(1<<bits-1)-1;
    if (sign) buf_set(buf);
    buf_winc(buf);
    for(i=1<<bits-2;i!=0;i>>=1) {
        if (mag&i) buf_set(buf);
        buf_winc(buf);
    }*/
/* Hardware compatable version: sign mag(lsb->msb) */
    int     i, mag=abs(lev);
    Boolean sign=lev<0;

    if (1<<bits-1 <= mag) mag=(1<<bits-1)-1;
    if (sign) buf_set(buf);
    buf_winc(buf);
    for(i=1;i!=1<<bits-1;i<<=1) {
        if (mag&i) buf_set(buf);
        buf_winc(buf);
    }
}

/*  Function Name:  HuffEncodeSA
 *  Description:    Write a Huffman coded integer to bit file
 *  Arguments:  lev - integer value
 *  Returns:    no of bits used
 */

void    HuffEncode(int lev,Buf buf)
{
/*  int     level=abs(lev);

    if (level>1) buf_set(buf);
    buf_winc(buf);
    if(level>2 || level==1) buf_set(buf);
    buf_winc(buf);
    if (level!=0) {
        if (lev<0) buf_set(buf);
        buf_winc(buf);
        if (level>2) {
            int     i;

            for(i=3;i<level;i++) {
                buf_winc(buf);
            }
            buf_set(buf);
            buf_winc(buf);
        }
```

```
    }*/

/* New version */
    int     level=abs(lev), i;

    if (level!=0) buf_set(buf);
    buf_winc(buf);
    if (level!=0) {
        if (lev<0) buf_set(buf);
        buf_winc(buf);
        if (level<8) {
            while (1<level--)
                buf_winc(buf);
            buf_set(buf);
            buf_winc(buf);
        } else {
            for(i=0;i<7;i++)
                buf_winc(buf);
            level-=8;
            for(i=1<<6;i!=0;i>>=1) {
                if (level&i) buf_set(buf);
                buf_winc(buf);
            }
        }
    }
}

/*  Function Name:  KlicsEChannel
 *  Description:    Encode a channel of image
 *  Arguments:  src - source channel memory
 *              dst - destination memory (and old for videos)
 *              octs, size - octaves of decomposition and image dimensions
 *              normals - HVS weighted normals
 *              lpf_bits - no of bits for LPF integer (image coding only)
 */

void    KlicsEncY(short *src,short *dst,int octs,int size[2],int thresh[5], int co
{
    int     oct, mask, x, y, sub, tmp, step=2<<octs, blk[4], mode[4], nz, no, base
    int     addr[4], new[4], old[4], pro[4], lev[4], zero[4]={0,0,0,0};
    Boolean nzflag, noflag, origin;
    int     bitmask=-1<<kle->seqh.precision-kle->frmh.quantizer[0]-1;
    Buf     buf=&kle->buf;

    for(y=0;y<size[1];y+=step)
    for(x=0;x<size[0];x+=step)
    for(sub=0;sub<4;sub++) {
    mode[oct=octs-1]=base_mode;
    if (sub==0) mode[oct=octs-1] |= M_LPF;
    mask=2<<oct;
    do {
        GetAddr(addr,x,y,sub,oct,size,mask);
        switch(mode[oct]) {
        case M_VOID:
            GetData(addr,old,dst);
            if (BlkZero(old)) mode[oct]=M_STOP;
            else { DoZero(addr,dst,mode,oct); }
            break;
        case M_SEND|M_STILL:
            GetData(addr,new,src);
            nz=Decide(new); nzflag=nz<=thresh[octs-oct];
            if (nzflag || Quantize(new,zero,pro,lev,kle->frmh.quantizer[octs-oct])
                GetData(addr,old,dst);
```

```
        if (BlkZero(old)) {
            Token0;
            mode[oct]=M_STOP;
        } else {
            Token1; Token1;
            DoZero(addr,dst,mode,oct);
        }
    } else {
        Token1; Token0;
        DoXfer(addr,pro,lev,dst,mode,oct,M_SEND|M_STILL,buf);
    }
    break;
case M_SEND:
    GetData(addr,new,src);
    GetData(addr,old,dst);
    nz=Decide(new); nzflag=nz<=thresh[octs-oct];
    if (BlkZero(old)) {
        if (nzflag || Quantize(new,zero,pro,lev,kle->frmh.quantizer[octs-o
            Token0;
            mode[oct]=M_STOP;
        } else {
            Token1; Token0;
            DoXfer(addr,pro,lev,dst,mode,oct,M_SEND|M_STILL,buf);
        }
    } else {
        int     oz=Decide(old), no=DecideDelta(new,old);
        Boolean motion=(nz+oz)>>oct <= no; /* motion detection */

        no=DecideDelta(new,old); noflag=no<=compare[octs-oct];
        origin=nz<=no;
            if ((!noflag || motion)  && !nzflag) { /* was !noflag && !nzfl
            if (Quantize(new,origin?zero:old,pro,lev,kle->frmh.quantizer[o
                Token1; Token1; Token0;
                DoZero(addr,dst,mode,oct);
            } else {
                if (origin) {
                    Token1; Token0;
                    DoXfer(addr,pro,lev,dst,mode,oct,M_SEND|M_STILL,buf);
                } else {
                    Token1; Token1; Token1;
                    DoXfer(addr,pro,lev,dst,mode,oct,M_SEND,buf);
                }
            }
        } else {
                if ((motion || origin) && nzflag) { /* was origin && nzfla
                Token1; Token1; Token0;
                DoZero(addr,dst,mode,oct);
            } else {
                Token0;
                mode[oct]=M_STOP;
            }
        }
    }
    break;
case M_STILL:
    GetData(addr,new,src);
    nz=Decide(new); nzflag=nz<=thresh[octs-oct];
    if (nzflag || Quantize(new,zero,pro,lev,kle->frmh.quantizer[octs-oct]))
        Token0;
        mode[oct]=M_STOP;
    } else {
        Token1;
        DoXfer(addr,pro,lev,dst,mode,oct,M_STILL,buf);
```

```
            }
            break;
        case M_LPF|M_STILL:
            GetData(addr,new,src);
            QuantizeLPF(new,pro,lev,kle->frmh.quantizer[0]);
            VerifyData(lev[0],bitmask,tmp);
            VerifyData(lev[1],bitmask,tmp);
            VerifyData(lev[2],bitmask,tmp);
            VerifyData(lev[3],bitmask,tmp);
            IntEncLev(lev,kle->seqh.precision-kle->frmh.quantizer[0],buf);
            PutData(addr,pro,dst);
            mode[oct]=M_QUIT;
            break;
        case M_LPF|M_SEND:
            GetData(addr,new,src);
            GetData(addr,old,dst);
            no=DecideDelta(new,old); noflag=no<=compare[octs-oct];
            if (noflag) {
                Token0;
            } else {
                Token1;
                Quantize(new,old,pro,lev,kle->frmh.quantizer[0]);
                HuffEncLev(lev,buf);
                PutData(addr,pro,dst);
            }
            mode[oct]=M_QUIT;
            break;
        }
        switch(mode[oct]) {
        case M_STOP:
            StopCounters(mode,oct,mask,blk,x,y,octs);
            break;
        case M_QUIT:
            break;
        default:
            DownCounters(mode,oct,mask,blk);
            break;
        }
    } while (mode[oct]!=M_QUIT);
    }
}

void    KlicsEncUV(short *src,short *dst,int octs,int size[2],int thresh[5], int c
{
    int     oct, mask, x, y, X, Y, sub, tmp, step=4<<octs, blk[4], mode[4], nz, no
    int     addr[4], new[4], old[4], pro[4], lev[4], zero[4]={0,0,0,0};
    Boolean nzflag, noflag, origin;
    int     bitmask=-1<<kle->seqh.precision-kle->frmh.quantizer[0]-1;
    Buf     buf=&kle->buf;

    for(Y=0;Y<size[1];Y+=step)
    for(X=0;X<size[0];X+=step)
    for(y=Y;y<size[1] && y<Y+step;y+=step>>1)
    for(x=X;x<size[0] && x<X+step;x+=step>>1)
    for(sub=0;sub<4;sub++) {
    mode[oct=octs-1]=base_mode;
    if (sub==0) mode[oct=octs-1] |= M_LPF;
    mask=2<<oct;
    do {
        GetAddr(addr,x,y,sub,oct,size,mask);
        switch(mode[oct]) {
        case M_VOID:
            GetData(addr,old,dst);
```

```
    if (BlkZero(old)) mode[oct]=M_STOP;
    else { DoZero(addr,dst,mode,oct); }
    break;
case M_SEND|M_STILL:
    GetData(addr,new,src);
    nz=Decide(new); nzflag=nz<=thresh[octs-oct];
    if (nzflag || Quantize(new,zero,pro,lev,kle->frmh.quantizer[octs-oct])
        GetData(addr,old,dst);
        if (BlkZero(old)) {
            Token0;
            mode[oct]=M_STOP;
        } else {
            Token1; Token1;
            DoZero(addr,dst,mode,oct);
        }
    } else {
        Token1; Token0;
        DoXfer(addr,pro,lev,dst,mode,oct,M_SEND|M_STILL,buf);
    }
    break;
case M_SEND:
    GetData(addr,new,src);
    GetData(addr,old,dst);
    nz=Decide(new); nzflag=nz<=thresh[octs-oct];
    if (BlkZero(old)) {
        if (nzflag || Quantize(new,zero,pro,lev,kle->frmh.quantizer[octs-o
            Token0;
            mode[oct]=M_STOP;
        } else {
            Token1; Token0;
            DoXfer(addr,pro,lev,dst,mode,oct,M_SEND|M_STILL,buf);
        }
    } else {
        int     oz=Decide(old), no=DecideDelta(new,old);
        Boolean motion=(nz+oz)>>oct <= no; /* motion detection */

        no=DecideDelta(new,old); noflag=no<=compare[octs-oct];
        origin=nz<=no;
            if ((!noflag || motion)  && !nzflag) { /* was !noflag && !nzfl
            if (Quantize(new,origin?zero:old,pro,lev,kle->frmh.quantizer[o
                Token1; Token1; Token0;
                DoZero(addr,dst,mode,oct);
            } else {
                if (origin) {
                    Token1; Token0;
                    DoXfer(addr,pro,lev,dst,mode,oct,M_SEND|M_STILL,buf);
                } else {
                    Token1; Token1; Token1;
                    DoXfer(addr,pro,lev,dst,mode,oct,M_SEND,buf);
                }
            }
        } else {
                if ((motion || origin) && nzflag) { /* was origin && nzfla
                Token1; Token1; Token0;
                DoZero(addr,dst,mode,oct);
            } else {
                Token0;
                mode[oct]=M_STOP;
            }
        }
    }
    break;
case M_STILL:
```

```
            GetData(addr,new,src);
            nz=Decide(new); nzflag=nz<=thresh[octs-oct];
            if (nzflag || Quantize(new,zero,pro,lev,kle->frmh.quantizer[octs-oct]);
                Token0;
                mode[oct]=M_STOP;
            } else {
                Token1;
                DoXfer(addr,pro,lev,dst,mode,oct,M_STILL,buf);
            }
            break;
        case M_LPF|M_STILL:
            GetData(addr,new,src);
            QuantizeLPF(new,pro,lev,kle->frmh.quantizer[0]);
            VerifyData(lev[0],bitmask,tmp);
            VerifyData(lev[1],bitmask,tmp);
            VerifyData(lev[2],bitmask,tmp);
            VerifyData(lev[3],bitmask,tmp);
            IntEncLev(lev,kle->seqh.precision-kle->frmh.quantizer[0],buf);
            PutData(addr,pro,dst);
            mode[oct]=M_QUIT;
            break;
        case M_LPF|M_SEND:
            GetData(addr,new,src);
            GetData(addr,old,dst);
            no=DecideDelta(new,old); noflag=no<=compare[octs-oct];
            if (noflag) {
                Token0;
            } else {
                Token1;
                Quantize(new,old,pro,lev,kle->frmh.quantizer[0]);
                HuffEncLev(lev,buf);
                PutData(addr,pro,dst);
            }
            mode[oct]=M_QUIT;
            break;
        }
        switch(mode[oct]) {
        case M_STOP:
            StopCounters(mode,oct,mask,blk,x,y,octs);
            break;
        case M_QUIT:
            break;
        default:
            DownCounters(mode,oct,mask,blk);
            break;
        }
    } while (mode[oct]!=M_QUIT);
    }
}

/* index to quant and vice versa */
#define i2q(i)  (float)i*HISTO_DELTA/(float)HISTO
#define q2i(q)  Fix2Long(X2Fix(q*(float)HISTO/HISTO_DELTA))


/*  Function Name:  LookAhead
 *  Description:    Examine base of tree to calculate new quantizer value
 *  Arguments:  src - source channel memory
 *              dst - destination memory (and old for videos)
 *              octs, size - octaves of decomposition and image dimensions
 *              norms - base HVS weighted normals
 *  Returns:    calculates new quant
 */
```

Engineering:KlicsCode:CompPict:KlicsEnc.c

```
void    LookAhead(short *src,short *dst,float norms[5][3],KlicsE kle)
{
    int      x, y, sub, index, size[2]={kle->seqh.sequence_size[0],kle->seqh.sequen
             thresh[HISTO], quact[HISTO], target;
    int      new[4], old[4], addr[4], zero[4]={0,0,0,0};
    float    quant;

    for(index=0;index<HISTO;index++) {
        thresh[index]=0;
        quact[index]=0;
    }
    for(y=0;y<size[1];y+=2<<octs)
    for(x=0;x<size[0];x+=2<<octs)
    for(sub=1;sub<4;sub++) {
        float   q_thresh;
        int     nz, no, oz, blk;
        Boolean ozflag, origin, motion;

        GetAddr(addr,x,y,sub,octs-1,size,1<<octs);
        GetData(addr,new,src);
        GetData(addr,old,dst);
        nz=Decide(new);
        oz=Decide(old);
        no=DecideDelta(new,old);
        ozflag=kle->encd.intra || BlkZero(old);
        origin=nz<=no;
        motion=(nz+oz)>>octs <= no;
        q_thresh=(float)nz/DecideDouble(norms[1][1]);
        if (ozflag || origin) {
            float   qt=GuessQuantize(new,zero,norms[1][0]);

            q_thresh=q_thresh<qt?q_thresh:qt;
        } else {
            float   qt=GuessQuantize(new,old,norms[1][0]);

            q_thresh=q_thresh<qt?q_thresh:qt;
            if (!motion) {
                qt=(float)no/DecideDouble(norms[1][2]);
                q_thresh=q_thresh<qt?q_thresh:qt;
            }
        }
        index=q2i(q_thresh);
        index=index<0?0:index>HISTO-1?HISTO-1:index;
        thresh[index]++;
    }
    for(index=HISTO-1;index>=0;index--)
        quact[index]=thresh[index]*index+(index==HISTO-1?0:quact[index+1]);

    /* buffer must be greater than bfp_in after this frame */
    /* buffer must be less than buff_size+bfp_in */
    target=kle->encd.bpf_out*kle->encd.prevquact/kle->encd.prevbytes; /* previous
    index=1;
    while(index<HISTO && quact[index]/index>target) index++;
    quant=i2q(index);

    kle->encd.tmp_quant=(kle->encd.tmp_quant+quant)/2.0;
    kle->encd.tmp_quant=i2q((index=q2i(kle->encd.tmp_quant))); /* forward and reve

    kle->encd.prevquact=quact[index]/(index==0?1:index);
}

/*  Function Name:  BaseNormals
```

Engineering:KlicsCode:CompPict:KlicsEnc.c

```
 * Description:    Calculates base HVS weighted normals
 * Arguments:  norms - storage for normals
 * Returns:    weighted normals
 */

void    BaseNormals(float norms[5][3],KlicsE kle)
{
    float   base_norm[3]={1.0,kle->encd.thresh,kle->encd.compare};
    int     norm, oct;

    for(oct=0;oct<5;oct++)
        for(norm=0;norm<3;norm++)
            norms[oct][norm]=base_norm[norm]*kle->encd.base[oct]*(float)(1<<kl
}

/* Function Name:  Normals
 * Description:    Calculates HVS weighted normals @ quant
 * Arguments:  norms - storage for normals
 * Returns:    weighted normals and LPF bits
 */

void    Normals(float base_norms[5][3],int thresh[5],int compare[5],KlicsE kle)
{

    int     oct, i, norm;

    for(oct=0;oct<=kle->seqh.octaves[0];oct++) {
        norm=Fix2Long(X2Fix(base_norms[oct][0]*kle->encd.tmp_quant));
        norm=norm<1?1:norm;
        for(i=0;0!=(norm&-3);i++)
            norm=norm>>1;
        switch(norm) {
        case 1:
            kle->frmh.quantizer[oct]=i;
            break;
        case 2:
            kle->frmh.quantizer[oct]=i+1;
            break;
        case 3:
        case 4:
            kle->frmh.quantizer[oct]=i+2;
        }
        thresh[oct]=Fix2Long(X2Fix(DecideDouble(base_norms[oct][1]*kle->encd.tmp_q
        compare[oct]=Fix2Long(X2Fix(DecideDouble(base_norms[oct][2]*kle->encd.tmp_
    }
    kle->frmh.quantizer[0]=kle->frmh.quantizer[0]<3?3:kle->frmh.quantizer[0];
    /* minimum 4 bits of quant for lpf due to dynamic range problems */
}

Boolean KlicsFlags(KlicsE kle)
{
    Boolean skip=false;

    kle->encd.buffer-=kle->encd.bpf_in;
    kle->frmh.flags=0;
    if (kle->encd.buffer<0)
        kle->encd.buffer=0;
    if (kle->encd.intra)
        kle->frmh.flags |= KFH_INTRA;
    else
        if (skip=kle->encd.buf_sw && kle->encd.buffer>=kle->encd.buf_size)
            kle->frmh.flags |= KFH_SKIP;
    return(skip);
```

Engineering:KlicsCode:CompPict:KlicsEnc.c

```
/*
 * Function Name:  KlicsEncode
 * Description:    Encode a frame from YUV (de)transformed image
 * Arguments:  src - source image(s)
 *             dst - transformed destination memory (and old for videos)
 */

long    KlicsEncode(short *src[3], short *dst[3], KlicsE kle)
{
    float   base_norms[5][3];
    int     channel, thresh[5], compare[5];
    Buf     buf=&kle->buf;

    buf_winit(buf)
    if (KlicsFlags(kle))
        kle->frmh.length=0;
    else {
        for(channel=0;channel<kle->seqh.channels;channel++) {
            int     size[2]={kle->seqh.sequence_size[0]>>(channel==0?0:kle->seqh.s
                        kle->seqh.sequence_size[1]>>(channel==0?0:kle->seqh.su
                    area=size[0]*size[1], octs=kle->seqh.octaves[channel==0?0:

            switch(kle->seqh.wavelet) {
            case WT_Haar:
                HaarForward(src[channel],size,octs);
                break;
            case WT_Daub4:
                Daub4Forward(src[channel],size,octs);
                break;
            }
        }
        BaseNormals(base_norms,kle);
        if (kle->encd.auto_q && !kle->encd.intra)
            LookAhead(src[0],dst[0],base_norms,kle);
        else
            kle->encd.tmp_quant=kle->encd.quant;
        Normals(base_norms,thresh,compare,kle);
        for(channel=0;channel<kle->seqh.channels;channel++) {
            int     size[2]={kle->seqh.sequence_size[0]>>(channel==0?0:kle->seqh.s
                        kle->seqh.sequence_size[1]>>(channel==0?0:kle->seqh.sub_sa
                    octs=kle->seqh.octaves[channel==0?0:1];

            if (kle->encd.intra)
                KLZERO(dst[channel],size[0]*size[1]);
            if (channel==0) KlicsEncY(src[channel],dst[channel],octs,size,thresh,c
            else KlicsEncUV(src[channel],dst[channel],octs,size,thresh,compare,kle
        }
        buf_flush(buf);
        kle->frmh.length=buf_size(buf);
        kle->encd.buffer+=kle->frmh.length;
        if (!kle->encd.intra)
            kle->encd.prevbytes=kle->frmh.length;
    }
    return(kle->frmh.length);
}
```

Engineering:KlicsCode:CompPict:KlicsHeader.h

```
/*******************************
 *
 * © Copyright 1993 KLICS Limited
 * All rights reserved.
 *
 * Written by: Adrian Lewis
 *
 ********************************/
/*
 * Sequence and frame headers for Klics-Encoded files
 * High byte first
 */

typedef struct {
    unsigned short  description_length; /* Fixed    - Size of this or parent struc
    unsigned char   version_number[2];  /* Fixed    - Version and revision numbers
} KlicsHeader;

typedef struct {
    KlicsHeader head;                   /* Fixed    - Size and version of this str
    unsigned short  sequence_size[3];   /* Source   - Luminance dimensions and num
    unsigned char   channels;           /* Source   - Number of channels: 3 - YUV,
    unsigned char   sub_sample[2];      /* Source   - UV sub-sampling in X and Y d
    unsigned char   wavelet;            /* Source   - Wavelet used: 0 - Haar, 1 -
    unsigned char   precision;          /* Source   - Bit precision for transform
    unsigned char   octaves[2];         /* Source   - Number of octaves Y/UV (maxi
    unsigned char   reserved[3];        /* Fixed    - Reserved for future use */
} KlicsSeqHeader;

typedef struct {
    KlicsHeader head;                   /* Fixed    - Size and version of this str
    unsigned long   length;             /* Calc     - Length of frame data (bytes)
    unsigned long   frame_number;       /* Calc     - Frame number intended for se
    unsigned char   flags;              /* Calc     - Bitfield flags: 0 - frame sk
    unsigned char   quantizer[5];       /* Calc     - Quantiser shift values(octav
    unsigned short  reserved;           /* Fixed    - Reserved for future use */
} KlicsFrameHeader;

#define KFH_SKIP    0x1
#define KFH_INTRA   0x2

/*
 * Implementation notes :
 *     QuickTime    Must have KlicsFrameHeader.length set to a valid number
 *     Sun          Must have KlicsSeqHeader in data stream
 *
 * Possible developments:
 *     KlicsFrameHeader.quantizer
 *         Currently contains shift rather than step-size
 *         Different values for UV and GH,HG,GG sub-bands are not currently suppo
 */
```

Engineering:KlicsCode:Klics Codec:KlicsEncode.r

```
/*
 * KlicsEncode resource file
 */


#include "Types.r"
#include "MPWTypes.r"
#include "ImageCodec.r"

/*
 * Klics Compressor included into the applications resource file here
 */

#define klicsCodecFormatName    "Klics"
#define klicsCodecFormatType    'klic'


/*

    This structure defines the capabilities of the codec. There will
    probably be a tool for creating this resource, which measures the performance
    and capabilities of your codec.

*/
resource 'cdci' (129, "Klics CodecInfo", locked) {
    klicsCodecFormatName,                           /* name of the codec TYPE ( da
    1,                                              /* version */
    1,                                              /* revision */
    'klic',                                         /* who made this codec */
    0,
    codecInfoDoes32|codecInfoDoes8|codecInfoDoesTemporal,   /* depth and etc suppo
    codecInfoDepth24|codecInfoSequenceSensitive,    /* which data formats do we un
    100,                                            /* compress accuracy (0-255) (
    100,                                            /* decompress accuracy (0-255)
    0,                                              /* millisecs to compress 320x2
    0,                                              /* millisecs to decompress 320.
    0,                                              /* compression level (0-255) (
    0,
    32,                                             /* minimum height */
    32,                                             /* minimum width */
    0,
    0,
    0
};

resource 'thng' (128,  "Klics Compressor", locked) {
    compressorComponentType,
    klicsCodecFormatType,
    'klic',
    codecInfoDoes32|codecInfoDoes8|codecInfoDoesTemporal,
    0,
    'cdec',
    128,
    'STR ',
    128,
    'STR ',
    129,
    'ICON',
    128
};

resource 'STR ' (128) {
    "Klics Compress"
```

Engineering:KlicsCode:Klics Codec:KlicsEncode.r

```
};

resource 'STR ' (129) {
    "Wavelet transform & multiresolution tree based coding scheme"
};
```

Engineering:KlicsCode:Klics Codec:KlicsDecode.r

```
/*
 *  KlicsDecode resource file
 */


#include "Types.r"
#include "MPWTypes.r"
#include "ImageCodec.r"

/*
 *  Klics Compressor included into the applications resource file here
 */

#define klicsCodecFormatName    "Klics"
#define klicsCodecFormatType    'klic'


/*

    This structure defines the capabilities of the codec. There will
    probably be a tool for creating this resource, which measures the performance
    and capabilities of your codec.

*/
resource 'cdci' (129, "Klics CodecInfo",locked) {
    klicsCodecFormatName,                               /* name of the codec TYPE ( da
    1,                                                  /* version */
    1,                                                  /* revision */
    'klic',                                             /* who made this codec */
    codecInfoDoes32|codecInfoDoes16|codecInfoDoes8|codecInfoDoesTemporal|codecInfo
    0,
    codecInfoDepth24|codecInfoSequenceSensitive,        /* which data formats do we un
    100,                                                /* compress accuracy (0-255) (
    100,                                                /* decompress accuracy (0-255)
    0,                                                  /* millisecs to compress 320x2
    0,                                                  /* millisecs to decompress 320
    0,                                                  /* compression level (0-255) (
    0,
    32,                                                 /* minimum height */
    32,                                                 /* minimum width */
    0,
    0,
    0
};

resource 'thng' (130,  "Klics Decompressor",locked) {
    decompressorComponentType,
    klicsCodecFormatType,
    'klic',
    codecInfoDoes32|codecInfoDoes16|codecInfoDoes8|codecInfoDoesTemporal|codecInfo
    0,
    'cdec',
    128,
    'STR ',
    130,
    'STR ',
    131,
    'ICON',
    130
};


resource 'STR ' (130) {
```

CLAIMS

WE CLAIM:

1. A method of transforming a sequence of input digital data values into a first sequence of transformed digital data values and of inverse transforming a second sequence of transformed digital data values into a sequence of output digital data values, said sequence of input digital data values comprising a boundary subsequence and a non-boundary subsequence, comprising the steps of:

running a number of said input digital data values of said boundary subsequence through a low pass boundary forward transform perfect reconstruction digital filter and through a high pass boundary forward transform perfect reconstruction digital filter to produce a first subsequence of said first sequence of transformed digital data values, said first subsequence of said first sequence of transformed digital data values comprising interleaved low and high frequency transformed digital data values;

running a number of said input digital data values of said non-boundary subsequence through a low pass non-boundary forward transform perfect reconstruction digital filter and also through a high pass non-boundary forward transform perfect reconstruction digital filter to produce a second subsequence of said first sequence of transformed digital data values, said second subsequence of said first sequence of transformed digital data values comprising interleaved low and high frequency transformed digital data values, said low pass boundary forward transform perfect reconstruction digital filter having a fewer number of coefficients than said low pass non-boundary forward transform perfect reconstruction digital filter, said high pass boundary forward transform perfect reconstruction digital filter having a fewer number of coefficients

than said high pass non-boundary forward transform perfect reconstruction digital filter;

converting said first sequence of transformed digital data values into said second sequence of transformed digital data values, said second sequence of transformed digital data values comprising a first subsequence of said second sequence of transformed digital data values and a second subsequence of said second sequence of transformed digital data values;

running a number of said first subsequence of said second sequence of transformed digital data values through an interleaved boundary inverse transform perfect reconstruction digital filter to produce at least one output digital data value;

running a number of said second subsequence of said second sequence of transformed digital data values through a first interleaved non-boundary inverse transform perfect reconstruction digital filter to produce output digital data values; and

running a number of said second subsequence of transformed digital data values through a second interleaved non-boundary inverse transform perfect reconstruction digital filter to produce output digital data values, said output digital data values produced by said interleaved boundary inverse transform perfect reconstruction digital filter, said first interleaved non-boundary inverse transform perfect reconstruction digital filter, and said second interleaved non-boundary inverse transform perfect reconstruction digital filter comprising a subsequence of said output digital data values of said sequence of output digital data values.

2. The method of Claim 1, wherein said low pass boundary forward transform perfect reconstruction digital filter has X coefficients and wherein said low pass non-boundary forward transform perfect reconstruction digital

filter has Y coefficients, Y being greater than X, said X coefficients of said low pass boundary forward transform perfect reconstruction digital filter being chosen so that said low pass boundary forward transform perfect reconstruction digital filter outputs a transformed digital data value H_0 when the low pass boundary forward perfect transform reconstruction digital filter operates on input digital data values ID_0-ID_{X-1} adjacent said boundary, said transformed digital data value H_0 being substantially equal to what the output of the low pass non-boundary forward transform perfect reconstruction digital filter would be were the low pass non-boundary forward perfect reconstruction digital filter to operate on ID_0-ID_{X-1} as well as Y-X additional input digital data values outside said boundary, said additional input digital data values having preselected values.

3. The method of Claim 2, wherein Y-X=1, wherein there is one additional input digital data value ID_{-1}, and wherein ID_{-1} is preselected to be substantially equal to ID_0.

4. The method of Claim 2, wherein Y-X=1, wherein there is one additional input digital data value ID_{-1}, and wherein ID_{-1} is preselected to be substantially equal to zero.

5. The method of Claim 1, wherein said sequence of input digital data values is a sequence of digital data values associated with pixels of either a row or a column of a two dimensional image, said boundary of said sequence of input digital data values corresponding with either a start or an end of said row or said column.

6. The method of Claim 1, wherein said sequence of input digital data values is a sequence of digital data values associated with an audio signal.

7. The method of Claim 1, wherein said low and high pass non-boundary forward transform perfect reconstruction digital filters are forward transform quasi-perfect reconstruction filters which have coefficients which approximate the coefficients of true forward transform perfect reconstruction filters.

8. The method of Claim 1, wherein said low and high pass non-boundary forward transform perfect reconstruction digital filters are both four coefficient quasi-Daubechies filters the coefficients of which approximate the coefficients of true four coefficient Daubechies filters.

9. The method of Claim 8, wherein one of said four coefficient quasi-Daubechies filters has the coefficients 11/32, 19/32, 5/32 and 3/32 independent of sign.

10. The method of Claim 1, wherein said low pass non-boundary forward transform perfect reconstruction digital filter is a four coefficient quasi-Daubechies filter H of the form:

$$H_n = aID_{2n-1} + bID_{2n} + cID_{2n+1} - dID_{2n+2}$$

n being a positive integer, ID_0-ID_m being input digital data values, m being a positive integer, ID_0 being the first input digital data value in said sequence of input digital data values, and wherein said low pass boundary forward transform perfect reconstruction digital filter is a three coefficient digital filter of the form:

$$H_0 = aID_{-1} + bID_0 + cID_1 - dID_2$$

ID_{-1} being a predetermined input digital data value outside said boundary and having a preselected value.

11. The method of Claim 10, wherein said high pass

non-boundary forward transform perfect reconstruction digital filter is a four coefficient quasi-Daubechies filter of the form:

$$G_n = dID_{2n-1} + cID_{2n} - bID_{2n+1} + aID_{2n+2}$$

n being a positive integer, and wherein said high pass boundary forward transform perfect reconstruction digital filter is a three coefficient digital filter of the form:

$$G_0 = dID_{-1} + cID_0 - bID_1 + aID_2$$

dID_{-1} having a preselected value.

12. The method of Claim 11, wherein: a + b + c - d is substantially equal to 1, wherein a - b + c + d is substantially equal to 0, and wherein ac - bd is substantially equal to zero.

13. The method of Claim 12, wherein: a=11/32, b=19/32, c=5/32 and d=3/32.

14. The method of Claim 11, wherein said interleaved boundary inverse transform perfect reconstruction digital filter is a two coefficient digital filter of the form:

$$OD_0 = 4(b-a)H_0 + 4(c-d)G_0$$

wherein OD_0 is an output digital data value of said sequence of output digital data values, wherein G_0 is the output of said high pass boundary forward transform perfect reconstruction digital filter when the high pass boundary forward transform perfect reconstruction digital filter operates on input digital data values ID_0, ID_1 and ID_2 adjacent said boundary, and wherein H_0 is the output of said low pass boundary forward transform perfect reconstruction digital filter when the low pass boundary

forward transform perfect reconstruction digital filter operates on input digital data values ID_0, ID_1 and ID_2 adjacent said boundary.

15. The method of Claim 14, wherein one of said first and second interleaved non-boundary inverse transform perfect reconstruction digital filters is of the form:

$$D_{2n+1} = 2(cH_n - bG_n + aH_{n+1} + dG_{n+1})$$

n being a non-negative integer, and wherein the other of said first and second interleaved non-boundary inverse perfect reconstruction digital filters is of the form:

$$D_{2n+2} = 2(-dH_n + aG_n + bH_{n+1} + cG_{n+1})$$

n being a non-negative integer, wherein H_n, G_n, H_{n+1} and G_{n+1} comprise a subsequence of said second sequence of transformed digital data values.

16. The method of Claim 1, wherein said low pass non-boundary forward transform perfect reconstruction digital filter is a four coefficient quasi-Daubechies filter having the coefficients: 11/32, 19/32, 5/32 and -3/32, and wherein said high pass non-boundary forward transform perfect reconstruction digital filter is a four coefficient quasi-Daubechies filter having the coefficients: 3/32, 5/32, -19/32 and 11/32.

17. The method of Claim 1, wherein said low and high pass non-boundary forward transform perfect reconstruction digital filters are chosen from the group consisting of: true six coefficient Daubechies filters and quasi-Daubechies filters, the coefficients of the quasi-Daubechies filters approximating the coefficients of true six coefficient Daubechies filters.

18. The method of Claim 1, further comprising the steps of:

encoding said first sequence of transformed digital data values into an encoded sequence; and

decoding said encoded sequence of digital data values into said second sequence of transformed digital data values and supplying said second sequence of transformed digital data values to said interleaved boundary inverse transform perfect reconstruction digital filter, said first interleaved non-boundary inverse transform perfect reconstruction digital filter, and said second interleaved non-boundary inverse transform perfect reconstruction digital filter.

19. The method of Claim 18, further comprising the step of:

quantizing each of said digital data values in said first sequence of transformed values before said encoding step.

20. The method of Claim 1, wherein each of said input digital data values of said sequence of input digital data values is stored in a separate memory location, and wherein some of said memory locations are overwritten in a sequence with said sequence of transformed digital data values as said digital data input values are transformed into said transformed digital data values.

21. A method of transforming a sequence of input digital data values into a sequence of transformed digital data values, said sequence of input digital data values comprising a boundary subsequence and a non-boundary subsequence, comprising the steps of:

running a number of said input digital data values of said boundary subsequence through a low pass boundary forward transform perfect reconstruction

digital filter and through a high pass boundary forward transform perfect reconstruction digital filter to produce a first subsequence of said sequence of transformed digital data values, said first subsequence of said sequence of transformed digital data values comprising interleaved low and high frequency transformed digital data values; and

running a number of said input digital data values of said non-boundary subsequence through a low pass non-boundary forward transform perfect reconstruction digital filter and also through a high pass non-boundary forward transform perfect reconstruction digital filter to produce a second subsequence of said sequence of transformed digital data values, said second subsequence of said sequence of transformed digital data values comprising interleaved low and high frequency transformed digital data values, said low pass boundary forward transform perfect reconstruction digital filter having a fewer number of coefficients than said low pass non-boundary forward transform perfect reconstruction digital filter, said high pass boundary forward transform perfect reconstruction digital filter having a fewer number of coefficients than said high pass non-boundary forward transform perfect reconstruction digital filter.

22. A method, comprising the steps of:

generating a sub-band decomposition having a plurality of octaves, a first of said plurality of octaves comprising at least one first digital data value, a second of said plurality of octaves comprising at least one second digital data value;

calculating a sum of the absolute values of said at least one first digital data value;

determining if said at least one first digital data value is interesting using a first threshold

limit;

calculating a sum of the absolute values of said at least one second digital data value; and

determining if said at least one second digital data value is interesting using a second threshold limit.

23. A method of traversing a tree decomposition, said tree decomposition comprising a plurality of transformed data values, each of said plurality of transformed data values having a unique address identified by coordinates X and Y, comprising the step of:

calculating at least four transformed data value addresses by incrementing a count, the count comprising one bit $C1_x$ in the X coordinate and one bit $C1_y$ in the Y coordinate, to generate said at least four transformed data value addresses.

24. A method, comprising the step of:

determining an address of a transformed data value in a tree decomposition by shifting a value a number of times, said tree decomposition having a number of octaves, said transformed data value being in one of said octaves, said number of times being at least dependent upon said one octave.

25. A method, comprising the step of:

determining an address of a transformed data value in a tree decomposition by multiplying a value by a factor, said tree decomposition having a number of octaves, said transformed data value being in one of said octaves, said factor being at least dependent upon said one octave.

26. A method, comprising the step of:

determining an address of a transformed data value in a tree decomposition by shifting a value a number of times, said tree decomposition having a number of frequency sub-

bands, said transformed data value being in one of said frequency sub-bands, said number of times being at least dependent upon said frequency sub-band.

27. A method, comprising the step of:

determining an address of a transformed data value in a tree decomposition by performing a logical operation upon a value, said tree decomposition having a number of frequency sub-bands, said transformed data value being in one of said frequency sub-bands, said logical operation performed being at least dependent upon said one frequency sub-band.

28. The method of Claim 27, wherein said logical operation is a bit-wise logical AND operation.

29. A method for determining a low pass quasi-perfect reconstruction filter and a high pass quasi-perfect reconstruction filter from a wavelet function, said low pass quasi-perfect reconstruction filter having a plurality of coefficients, said high pass quasi-perfect reconstruction filter having a plurality of coefficients, comprising the steps of:

determining a low pass wavelet digital filter and a high pass wavelet digital filter from said wavelet function, said low pass wavelet digital filter having a plurality of coefficients, said high pass wavelet digital filter having a plurality of coefficients;

choosing the coefficients of said low pass quasi-perfect reconstruction digital filter to be fractions such that when a sequence of data values having values of 1 is processed by said low pass quasi-perfect reconstruction digital filter the output of said low pass quasi-perfect reconstruction digital filter is exactly a power of 2; and

choosing the coefficients of the high pass quasi-perfect reconstruction digital filter to be fractions such that when a sequence of data values having values of 1 is

processed by said high pass quasi-perfect reconstruction digital filter the output of said high pass quasi-perfect reconstruction digital filter is exactly 0, whereby each of the plurality of coefficients of said low pass quasi-perfect reconstruction digital filter is substantially identical to a corresponding one of said plurality of coefficients of said low pass wavelet digital filter, and whereby each of the plurality of coefficients of said high pass quasi-perfect reconstruction digital filter is substantially identical to a corresponding one of said plurality of coefficients of said high pass wavelet digital filter.

30. A method of estimating a compression ratio of a number of original data values to a number of compressed data values at a value of a quality factor Q, comprising the steps of:

examining a first block of transformed data values of a tree, said first block being one of a number of lowest frequency blocks of a high pass component sub-band, said tree being part of a sub-band decomposition; and

determining a value of said quality factor Q at which said data values of said first block would be converted into compressed data values, and not determining a value of said quality factor Q at which any other block of data values of said tree would be converted into a number of compressed data values.

31. The method of Claim 30, wherein said number of original data values represents a frame of an image.

32. The method of Claim 31, further comprising the step of:

determining a number of lowest frequency blocks of said high pass component sub-band which would be converted into compressed data values given a value of said quality factor Q.

33. A method of transforming a sequence of image data values, comprising the step of:

filtering said sequence of image data values using a quasi-perfect reconstruction filter to generate a decomposition having a plurality of octaves, said quasi-perfect reconstruction filter having six coefficients.

34. The method of Claim 33, wherein said six coefficients are selected from the group consisting of: 30/128, 73/128, 41/128, 12/128, 7/128 and 3/128, irrespective of sign.

35. A method of detecting motion in a tree decomposition, said tree decomposition comprising a plurality of octaves of blocks of data values, comprising the steps of:

comparing data values of a first block in an octave with data values of a second block in said octave; and

generating a token indicating motion based on said comparing.

36. A method, comprising the steps of:

generating a sub-band decomposition having a plurality of octaves, a first of said plurality of octaves comprising at least one first digital data value, a second of said plurality of octaves comprising at least one second digital data value;

determining if said at least one first digital data value is interesting using a first threshold limit; and

determining if said at least one second digital data value is interesting using a second threshold limit.

37. A method, comprising the steps of:

generating a sub-band decomposition of a first frame having a plurality of octaves, a first of said plurality of octaves comprising at least one first digital data value, a

second of said plurality of octaves comprising at least one second digital data value;

generating a sub-band decomposition of a second frame having a plurality of octaves, a first of said plurality of octaves comprising at least one first digital data value, a second of said plurality of octaves comprising at least one second digital data value;

comparing said first digital data value of said first frame with said first digital data value of said second frame using a first threshold compare; and

comparing said second digital data value of said first frame with said second digital data value of said second frame using a second threshold compare.

38. A method, comprising the steps of:

reading a sequence of data values from a plurality of memory locations, each of said data values being stored in a separate one of said plurality of memory locations; and

overwriting some of said memory locations in a sequence as said data values are transformed into a sequence of transformed data values of a sub-band decomposition.

39. A method, comprising the steps of:

performing a function on a plurality of data values of a new block to generate a first output value, said new block being a block of data values of a sub-band decomposition of a new frame;

performing said function on a plurality of numbers to generate a second output value, each of said numbers substantially equalling a difference of a data value in said plurality of data values of said new block and a corresponding data value in a corresponding plurality of data values of an old block, said old block being a block of data values of a sub-band decomposition of an old frame; and

generating a token if said first output value has a

predetermined relationship with respect to said second output value.

40. The method of Claim 39, wherein said token is a SEND_STILL token.

41. A method, comprising the steps of:

performing a function on a plurality of data values of a new block to generate a corresponding plurality of output values, said new block being a block of data values of a sub-band decomposition;

comparing each of said plurality of output values with a predetermined number; and

generating a token if substantially all of said output values have a predetermined relationship with respect to said predetermined number.

42. The method of Claim 41, wherein said token is a VOID token.

43. A method, comprising the steps of:

subtracting each one of a plurality of data values of a new block with a corresponding one of a plurality of data values of a old block to generate a corresponding plurality of output values, said new block being a block of data values of a sub-band decomposition of a new frame, said old block being a block of data values of a sub-band decomposition of a old frame;

comparing each of said plurality of output values with a predetermined number; and

generating a token if substantially all of said output values have a predetermined relationship with respect to said predetermined number.

44. The method of Claim 43, wherein said token is a VOID token.

45. A method, comprising the steps of:

determining an absolute value for each of a plurality of data values of a block of a sub-band decomposition;

determining a sum of said absolute values; and

generating a token based on a comparison of said sum with a predetermined number.

46. The method of Claim 45, wherein said token is a VOID token.

47. A method, comprising the steps of:

processing a sequence of first image data values using a low pass forward transform perfect reconstruction digital filter and a high pass forward transform perfect reconstruction digital filter to create a first sequence of transformed data values, said low pass forward transform perfect reconstruction digital filter and said high pass forward transform perfect reconstruction digital filter each having coefficients chosen from a first group of coefficients independent of sign;

converting said first sequence of transformed data values into a second sequence of transformed data values; and

using digital circuitry to process said second sequence of transformed data values using a low pass inverse transform perfect reconstruction digital filter and a high pass inverse transform perfect reconstruction digital filter into a sequence of second image data values, said low pass inverse transform perfect reconstruction digital filter and said high pass inverse transform perfect reconstruction digital filter each having coefficients chosen from a second group of coefficients independent of sign.

48. The method of claim 47, wherein said digital circuitry used to process said second sequence of transformed data values is a digital computer having a

microprocessor.

49. The method of claim 47, wherein at least one of the coefficients in said first group of coefficients is not contained in said second group of coefficients.

50. The method of claim 47, wherein said first group of coefficients has a different number of coefficients than said second group of coefficients.

51. The method of claim 50, wherein said sequence of first image data values is a sequence of chrominance data values.

52. The method of claim 50, wherein said low pass forward transform perfect reconstruction digital filter and said high pass forward transform perfect reconstruction digital filter each have four coefficients, and wherein said low pass inverse transform perfect reconstruction digital filter and said high pass inverse transform perfect reconstruction digital filter each have two coefficients.

53. The method of claim 52, wherein said sequence of first image data values is a sequence of chrominance data values.

54. The method of claim 47, wherein each of said coefficients of said low pass inverse transform perfect reconstruction digital filter and said high pass inverse transform perfect reconstruction digital filter is selected from the group consisting of: 5/8, 3/8 and 1/8, independent of sign.

55. The method of claim 47, wherein said converting step comprises the steps of:

encoding said first sequence of transformed data values into a compressed data stream; and

decoding said compressed data stream into said second sequence of transformed data values.

56. A method comprising the step of using digital circuitry to process a sequence of image data values using a low pass forward transform perfect reconstruction digital filter and a high pass forward transform perfect reconstruction digital filter to generate a sub-band decomposition, said low pass forward transform perfect reconstruction digital filter and said high pass forward transform perfect reconstruction digital filter each having four coefficients, each of said four coefficients being selected from the group consisting of: 5/8, 3/8 and 1/8, independent of sign.

57. The method of claim 56, wherein said digital circuitry comprises means for low pass forward transform perfect reconstruction digital filtering and for high pass forward transform perfect reconstruction digital filtering.

58. A method comprising the step of using digital circuitry to process a sequence of transformed data values of a sub-band decomposition using an odd inverse transform perfect reconstruction digital filter and an even inverse transform perfect reconstruction digital filter, said odd inverse transform perfect reconstruction digital filter and said even inverse transform perfect reconstruction digital filter each having four coefficients, each of said four coefficients being selected from the group consisting of: 5/8, 3/8 and 1/8, independent of sign.

59. The method of claim 58, wherein said digital circuitry is a digital computer having a microprocessor.

60. A method comprising the step of generating a compressed data stream indicative of a video sequence from a sub-band decomposition, said compressed data stream

comprising a first data value, a first token, a second data value, and a second token, said first token being indicative of a first encoding method used to encode said first data value, said second token being indicative of a second encoding method used to encode said second data value, said first token consisting of a first number of bits and said second token consisting of a second number of bits.

61. The method of claim 60, wherein said first encoding method is taken from the group consisting of: SEND mode, STILL_SEND mode, VOID mode, and STOP mode.

62. The method of claim 60, wherein said first token is a single bit token.

63. A method, comprising the steps of:

forward transforming image data values to generate a first sequence of transformed data values of a first sub-band decomposition, said first sub-band decomposing having a first number of octaves;

converting said first sequence of transformed data values into a second sequence of transformed data values;

using digital circuitry to inverse transforming said second sequence of transformed data values into a third sequence of transformed data values, said third sequence of transformed data values comprising a second sub-band decomposition having a second number of octaves, said second number of octaves being smaller than said first number of octaves, said second sub-band decomposition having a low pass component, said low pass component of said second sub-band decomposition comprising data values indicative of rows of data values of an image, said rows of said image extending in a first dimension, said image also having columns of said data values extending in a second dimension;

expanding said low pass component in said first

dimension using interpolation to generate an interpolated low pass component; and

expanding said interpolated low pass component in said second dimension by replicating rows of said data values of said interpolated low pass component.

64. The method of claim 63, wherein said digital circuitry is a digital computer having a microprocessor.

65. The method of claim 63, wherein said converting step comprises the steps of:

encoding said first sequence of transformed data values into a compressed data stream comprising tokens and encoded data values; and

decoding said compressed data stream into said second sequence of transformed data values.

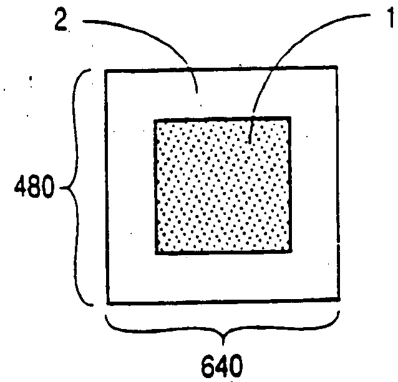


Fig. 1
(PRIOR ART)

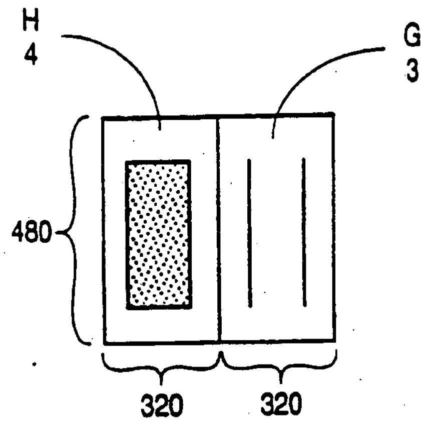


Fig. 2
(PRIOR ART)

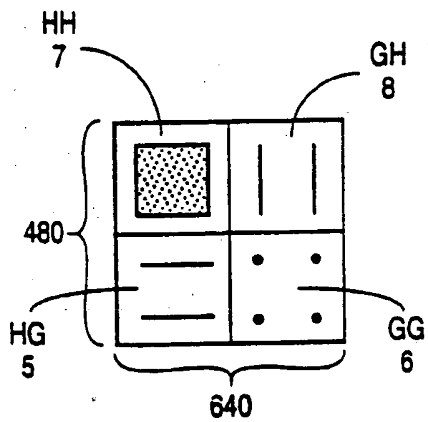


Fig. 3
(PRIOR ART)

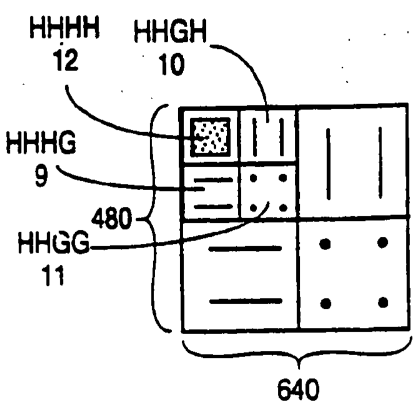


Fig. 4
(PRIOR ART)

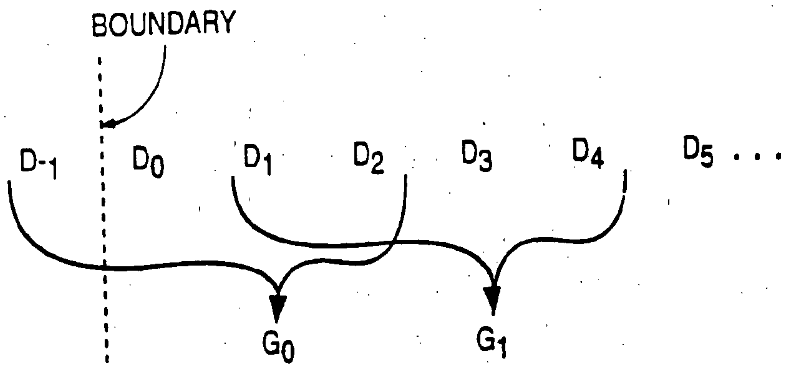


Fig. 5
(PRIOR ART)

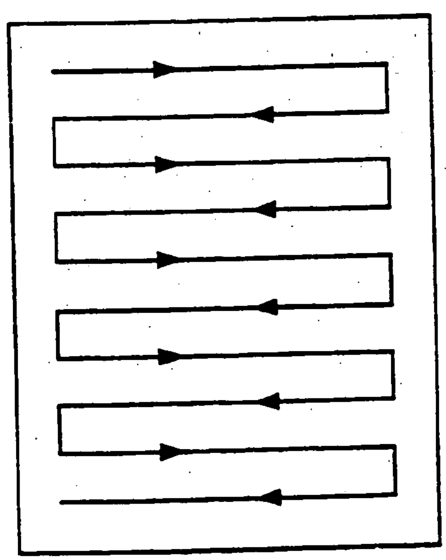


Fig. 6
(PRIOR ART)

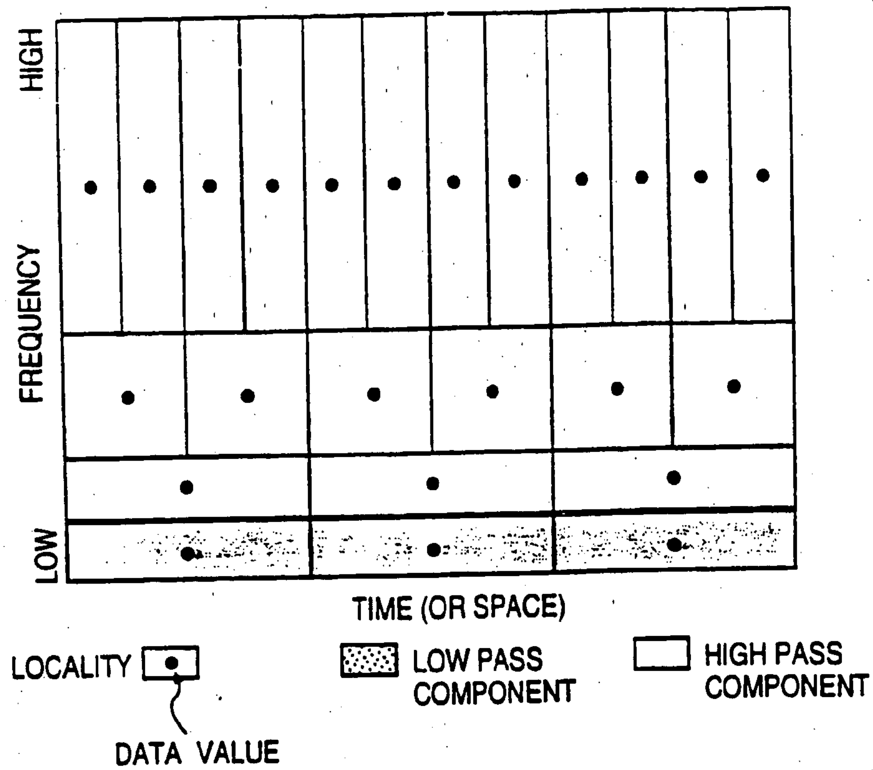


Fig. 7

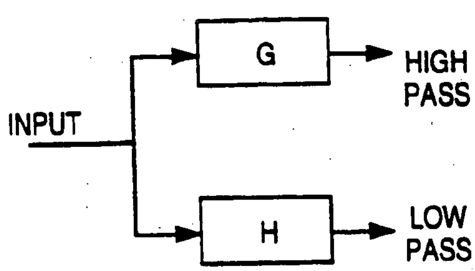


Fig. 8

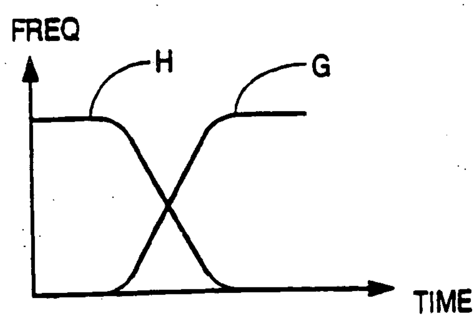


Fig. 9

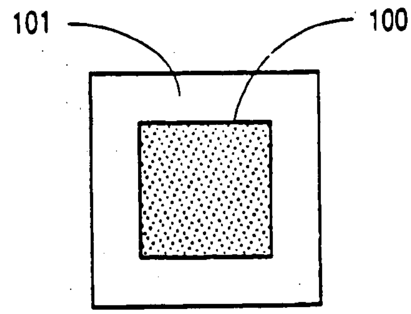


Fig. 10

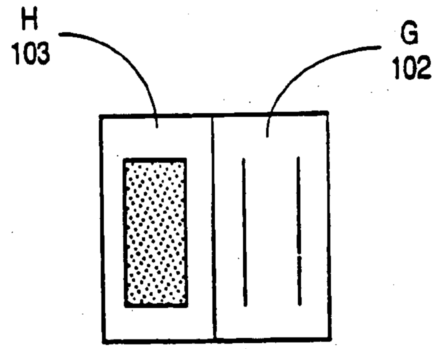


Fig. 11

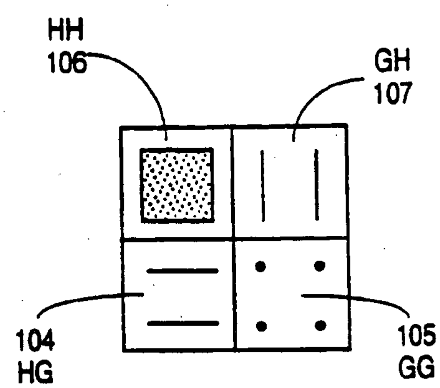


Fig. 14

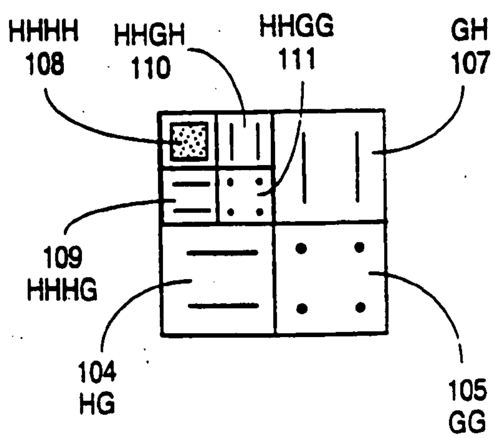


Fig. 15

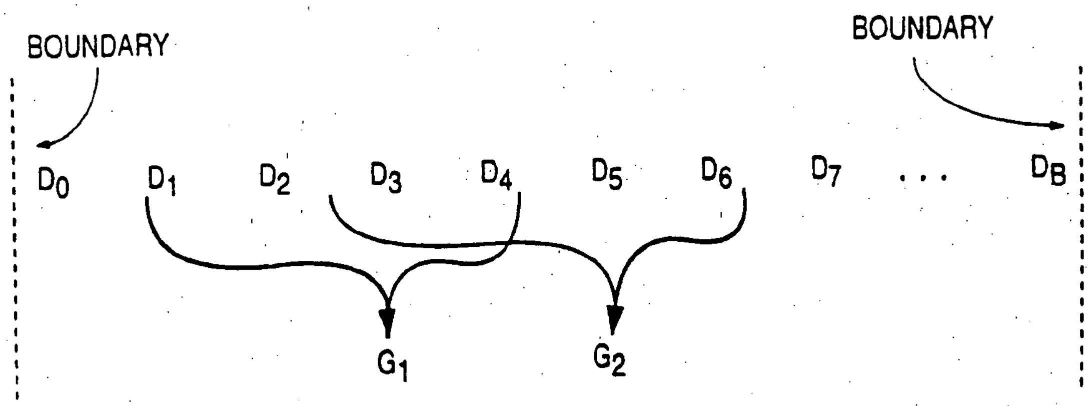

BOUNDARY
BOUNDARY
D_0 D_1 D_2 D_3 D_4 D_5 D_6 D_7 . . . D_B
G_1
G_2

Fig. 12

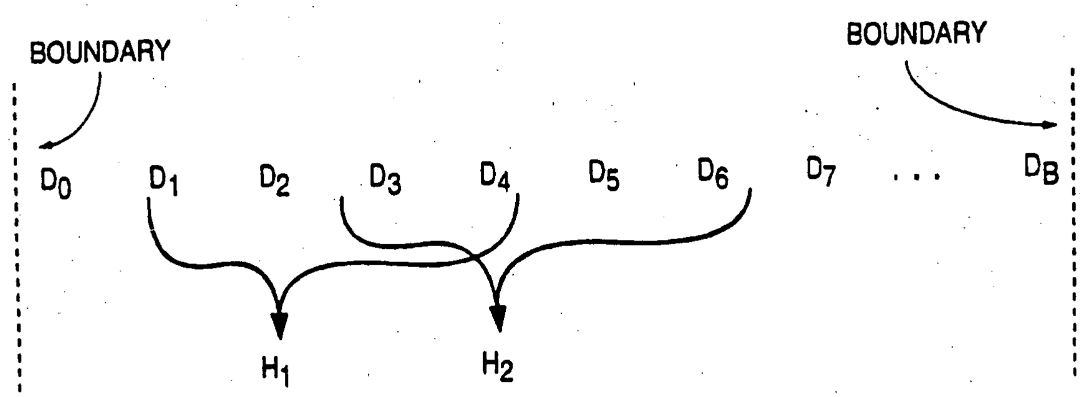

BOUNDARY
BOUNDARY
D_0 D_1 D_2 D_3 D_4 D_5 D_6 D_7 . . . D_B
H_1
H_2

Fig. 13

ROW \ COLUMN	0	1	2	3	4	5	6	7	8	9	A	B
0	D_{00}	D_{01}	D_{02}	D_{03}	D_{04}	D_{05}	D_{06}	D_{07}	D_{08}	D_{09}	D_{0A}	D_{0B}
1	D_{10}	D_{11}	D_{12}	D_{13}	D_{14}	D_{15}	D_{16}	D_{17}	D_{18}	D_{19}	D_{1A}	D_{1B}
2	D_{20}	D_{21}	D_{22}	D_{23}	D_{24}	D_{25}	D_{26}	D_{27}	D_{28}	D_{29}	D_{2A}	D_{2B}
3	D_{30}	D_{31}	D_{32}	D_{33}	D_{34}	D_{35}	D_{36}	D_{37}	D_{38}	D_{39}	D_{3A}	D_{3B}
4	D_{40}	D_{41}	D_{42}	D_{43}	D_{44}	D_{45}	D_{46}	D_{47}	D_{48}	D_{49}	D_{4A}	D_{4B}
5	D_{50}	D_{51}	D_{52}	D_{53}	D_{54}	D_{55}	D_{56}	D_{57}	D_{58}	D_{59}	D_{5A}	D_{5B}
6	D_{60}	D_{61}	D_{63}	D_{63}	D_{64}	D_{65}	D_{66}	D_{67}	D_{68}	D_{69}	D_{6A}	D_{6B}
7	D_{70}	D_{71}	D_{72}	D_{73}	D_{74}	D_{75}	D_{76}	D_{77}	D_{78}	D_{79}	D_{7A}	D_{7B}
8	D_{80}	D_{81}	D_{82}	D_{83}	D_{84}	D_{85}	D_{86}	D_{87}	D_{88}	D_{89}	D_{8A}	D_{8B}
9	D_{90}	D_{91}	D_{92}	D_{93}	D_{94}	D_{95}	D_{96}	D_{97}	D_{98}	D_{99}	D_{9A}	D_{9B}
A	D_{A0}	D_{A1}	D_{A2}	D_{A3}	D_{A4}	D_{A5}	D_{A6}	D_{A7}	D_{A8}	D_{A9}	D_{AA}	D_{AB}
B	D_{B0}	D_{B1}	D_{B2}	D_{B3}	D_{B4}	D_{B5}	D_{B6}	D_{B7}	D_{B8}	D_{B9}	D_{BA}	D_{BB}

Fig. 16

ROW \ COLUMN	0	1	2	3	4	5	6	7	8	9	A	B
0	HH_{00}	GH_{00}	HH_{01}	GH_{01}	HH_{02}	GH_{02}	HH_{03}	GH_{03}	HH_{04}	GH_{04}	HH_{05}	GH_{05}
1	HG_{00}	GG_{00}	HG_{01}	GG_{01}	HG_{02}	GG_{02}	HG_{03}	GG_{03}	HG_{04}	GG_{04}	HG_{05}	GG_{05}
2	HH_{10}	GH_{10}	HH_{11}	GH_{11}	HH_{12}	GH_{12}	HH_{13}	GH_{13}	HH_{14}	GH_{14}	HH_{15}	GH_{15}
3	HG_{10}	GG_{10}	HG_{11}	GG_{11}	HG_{12}	GG_{12}	HG_{13}	GG_{13}	HG_{14}	GG_{14}	HG_{15}	GG_{15}
4	HH_{20}	GH_{20}	HH_{21}	GH_{21}	HH_{22}	GH_{22}	HH_{23}	GH_{23}	HH_{24}	GH_{24}	HH_{25}	GH_{25}
5	HG_{20}	GG_{20}	HG_{21}	GG_{21}	HG_{22}	GG_{22}	HG_{23}	GG_{23}	HG_{24}	GG_{24}	HG_{25}	GG_{25}
6	HH_{30}	GH_{30}	HH_{31}	GH_{31}	HH_{32}	GH_{32}	HH_{33}	GH_{33}	HH_{34}	GH_{34}	HH_{35}	GH_{35}
7	HG_{30}	GG_{30}	HG_{31}	GG_{31}	HG_{32}	GG_{32}	HG_{33}	GG_{33}	HG_{34}	GG_{34}	HG_{35}	GG_{35}
8	HH_{40}	GH_{40}	HH_{41}	GH_{41}	HH_{42}	GH_{42}	HH_{43}	GH_{43}	HH_{44}	GH_{44}	HH_{45}	GH_{45}
9	HG_{40}	GG_{40}	HG_{41}	GG_{41}	HG_{42}	GG_{42}	HG_{43}	GG_{43}	HG_{44}	GG_{44}	HG_{45}	GG_{45}
A	HH_{50}	GH_{50}	HH_{51}	GH_{51}	HH_{52}	GH_{52}	HH_{53}	GH_{53}	HH_{54}	GH_{54}	HH_{55}	GH_{55}
B	HG_{50}	GG_{50}	HG_{51}	GG_{51}	HG_{52}	GG_{52}	HG_{53}	GG_{53}	HG_{54}	GG_{54}	HG_{55}	GG_{55}

Fig. 17

COLUMN

ROW	0	1	2	3	4	5	6	7	8	9	A	B
0	$HHHH_{00}$	GH_{00}	$HHGH_{00}$	GH_{01}	$HHHH_{01}$	GH_{02}	$HHGH_{01}$	GH_{03}	$HHHH_{02}$	GH_{04}	$HHGH_{02}$	GH_{05}
1	HG_{00}	GG_{00}	HG_{01}	GG_{01}	HG_{02}	GG_{02}	HG_{03}	GG_{03}	HG_{04}	GG_{04}	HG_{05}	GG_{05}
2	$HHHG_{00}$	GH_{10}	$HHGG_{00}$	GH_{11}	$HHHG_{01}$	GH_{12}	$HHGG_{01}$	GH_{13}	$HHHG_{02}$	GH_{14}	$HHGG_{02}$	GH_{15}
3	HG_{10}	GG_{10}	HG_{11}	GG_{11}	HG_{12}	GG_{12}	HG_{13}	GG_{13}	HG_{14}	GG_{14}	HG_{15}	GG_{15}
4	$HHHH_{10}$	GH_{20}	$HHGH_{10}$	GH_{21}	$HHHH_{11}$	GH_{22}	$HHGH_{11}$	GH_{23}	$HHHH_{12}$	GH_{24}	$HHGH_{12}$	GH_{25}
5	HG_{20}	GG_{20}	HG_{21}	GG_{21}	HG_{22}	GG_{22}	HG_{23}	GG_{23}	HG_{24}	GG_{24}	HG_{25}	GG_{25}
6	$HHHG_{10}$	GH_{30}	$HHGG_{10}$	GH_{31}	$HHHG_{11}$	GH_{32}	$HHGG_{11}$	GH_{33}	$HHHG_{12}$	GH_{34}	$HHGG_{12}$	GH_{35}
7	HG_{30}	GG_{30}	HG_{31}	GG_{31}	HG_{32}	GG_{32}	HG_{33}	GG_{33}	HG_{34}	GG_{34}	HG_{35}	GG_{35}
8	$HHHH_{20}$	GH_{40}	$HHGH_{20}$	GH_{41}	$HHHH_{21}$	GH_{42}	$HHGH_{21}$	GH_{43}	$HHHH_{22}$	GH_{44}	$HHGH_{22}$	GH_{45}
9	HG_{40}	GG_{40}	HG_{41}	GG_{41}	HG_{42}	GG_{42}	HG_{43}	GG_{43}	HG_{44}	GG_{44}	HG_{45}	GG_{45}
A	$HHHG_{20}$	GH_{50}	$HHGG_{20}$	GH_{51}	$HHHG_{21}$	GH_{52}	$HHGG_{21}$	GH_{53}	$HHHG_{22}$	GH_{54}	$HHGG_{22}$	GH_{55}
B	HG_{50}	GG_{50}	HG_{51}	GG_{51}	HG_{52}	GG_{52}	HG_{53}	GG_{53}	HG_{54}	GG_{54}	HG_{55}	GG_{55}

Fig. 18

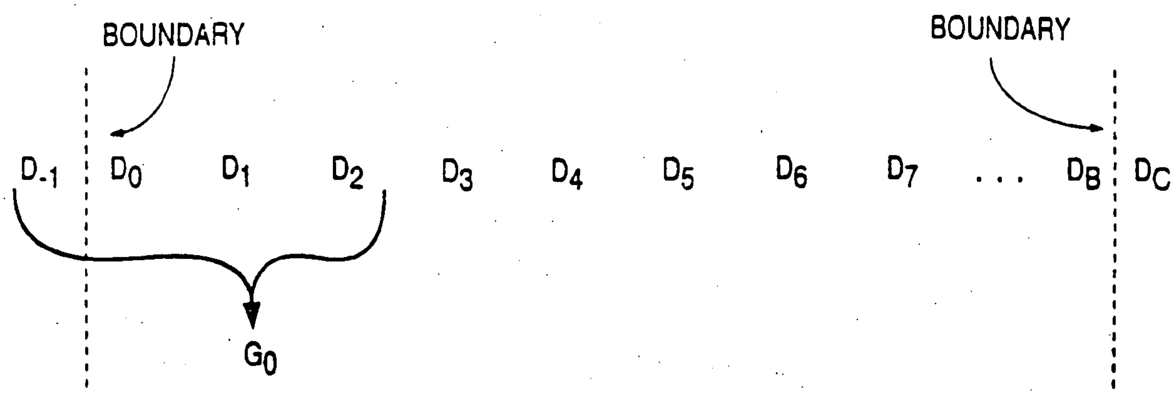

BOUNDARY
BOUNDARY
D_{-1} D_0 D_1 D_2 D_3 D_4 D_5 D_6 D_7 . . . D_B D_C
G_0

Fig. 19

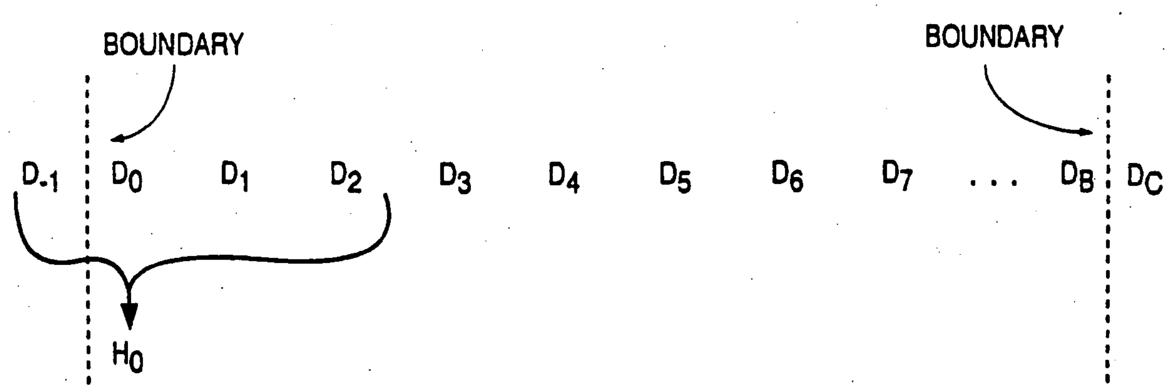

BOUNDARY
BOUNDARY
D_{-1} D_0 D_1 D_2 D_3 D_4 D_5 D_6 D_7 . . . D_B D_C
H_0

Fig. 20

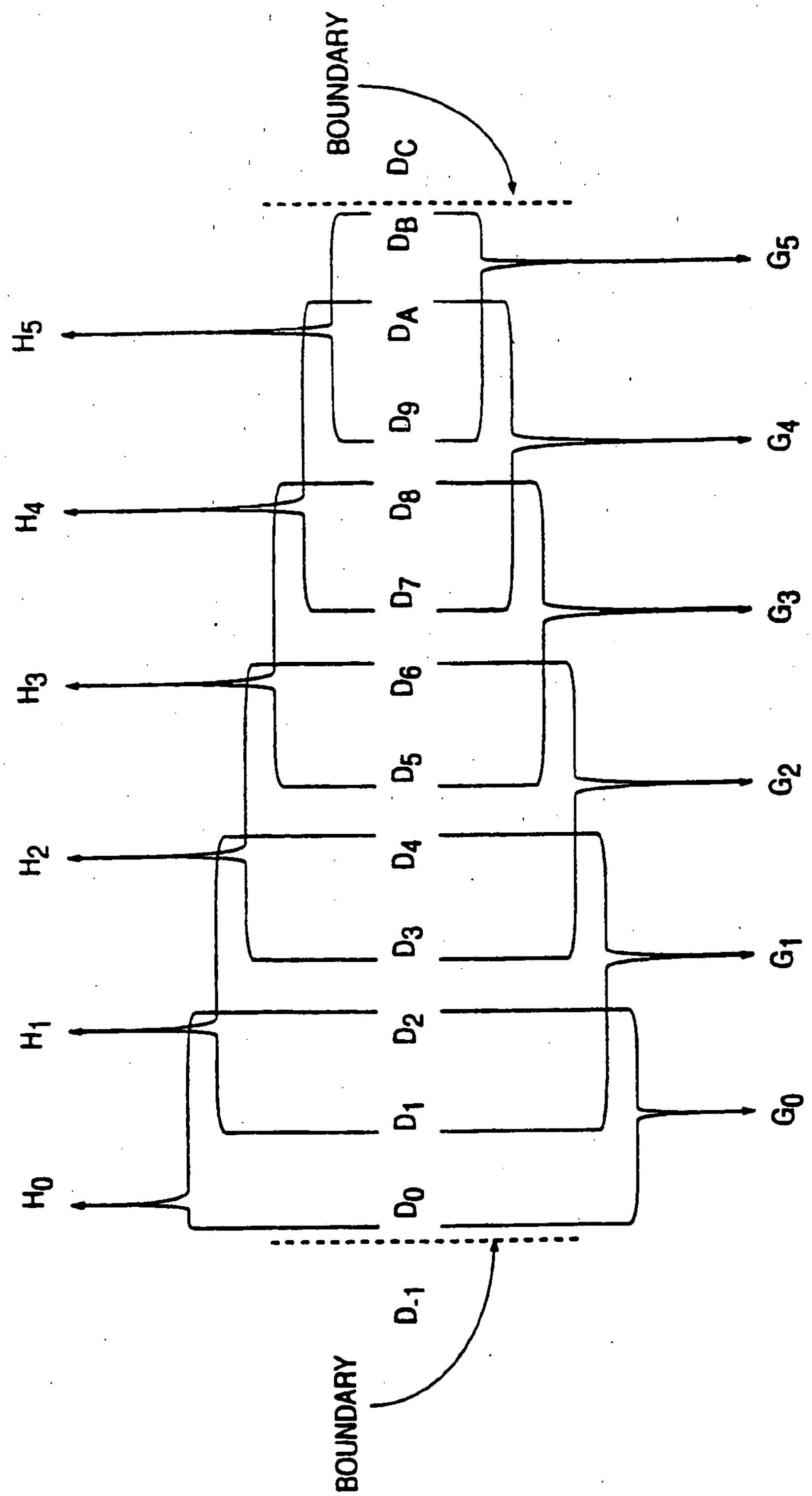
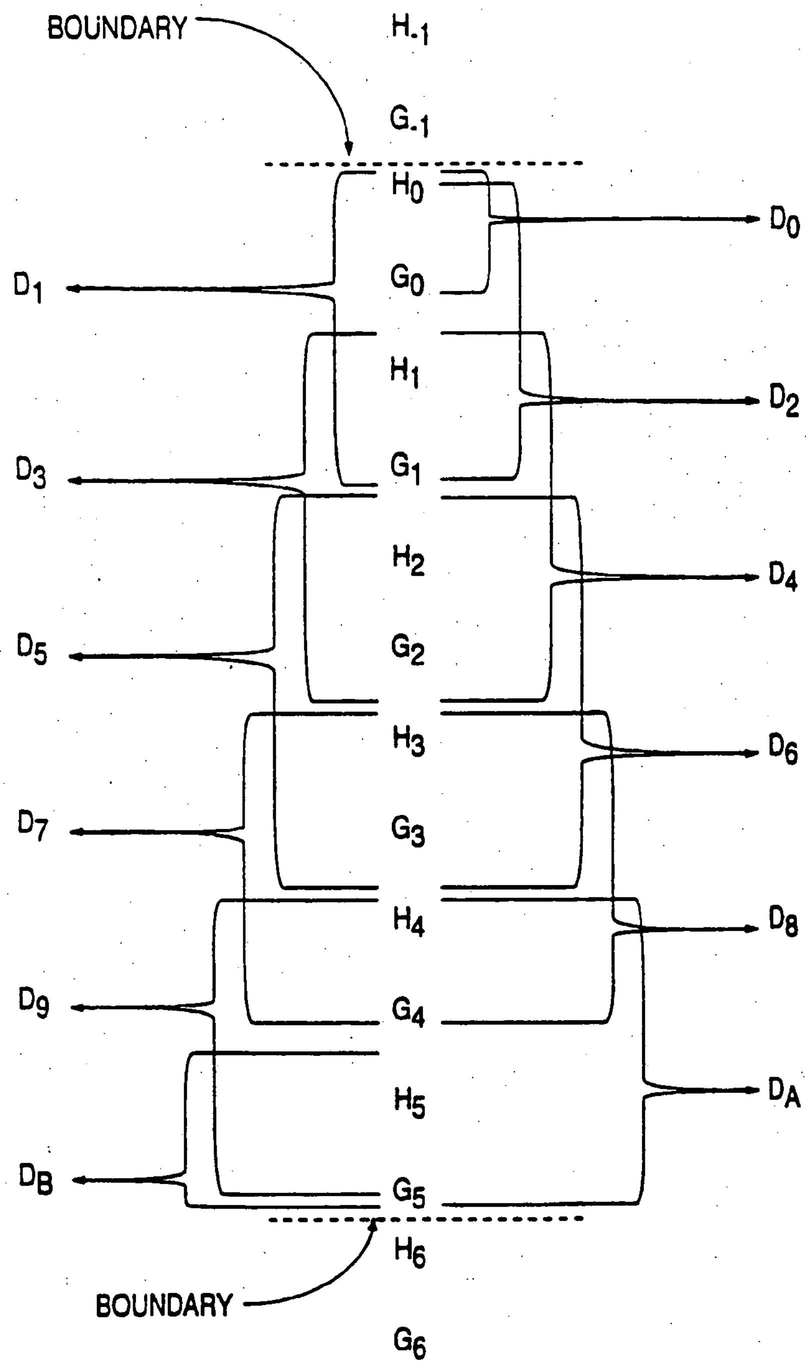

BOUNDARY
D_C
D_B
D_A
D_9
D_8
D_7
D_6
D_5
D_4
D_3
D_2
D_1
D_0
D_-1
BOUNDARY
H_5
H_4
H_3
H_2
H_1
H_0
G_5
G_4
G_3
G_2
G_1
G_0

Fig. 21


BOUNDARY
H_{-1}
G_{-1}
H_0
D_0
D_1
G_0
H_1
D_2
D_3
G_1
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G_2
H_3
D_6
D_7
G_3
H_4
D_8
D_9
G_4
H_5
D_A
D_B
G_5
H_6
BOUNDARY
G_6

Fig. 22

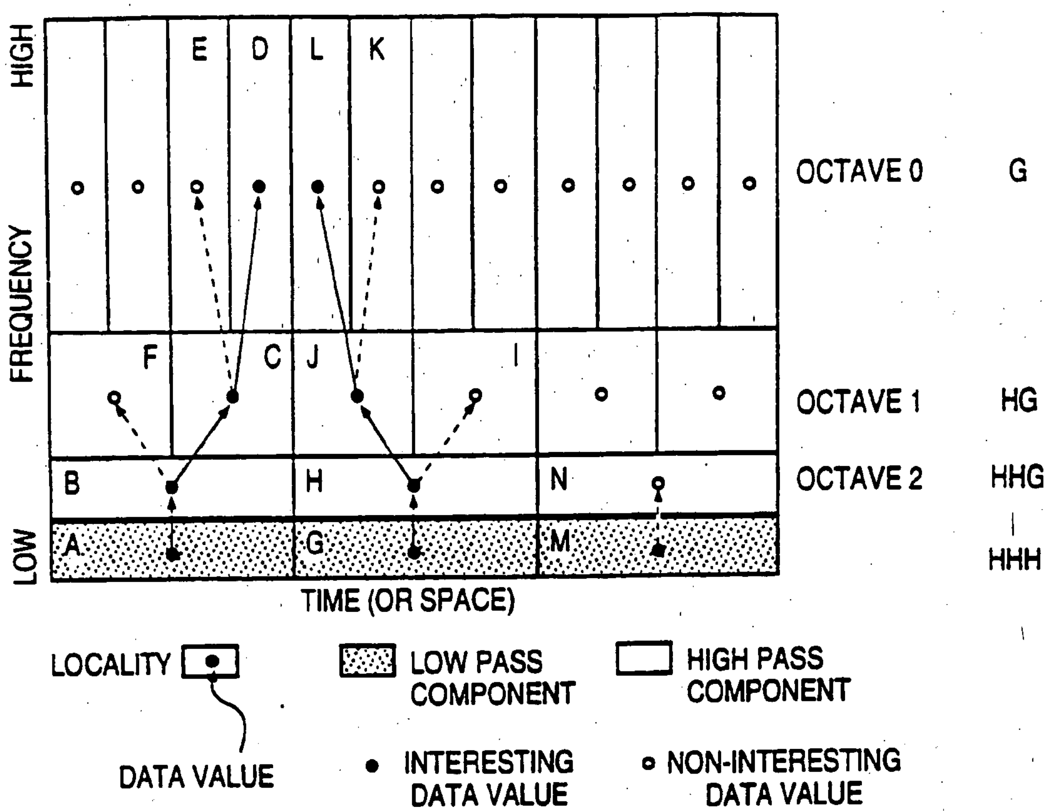

HIGH
FREQUENCY
LOW
E
D
L
K
F
C
J
I
B
H
N
A
G
M
OCTAVE 0
G
OCTAVE 1
HG
OCTAVE 2
HHG
HHH
TIME (OR SPACE)
LOCALITY
DATA VALUE
LOW PASS COMPONENT
HIGH PASS COMPONENT
INTERESTING DATA VALUE
NON-INTERESTING DATA VALUE

Fig. 23

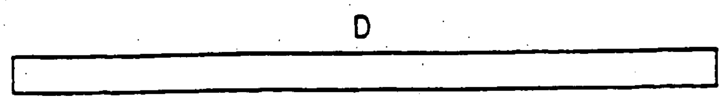


Fig. 24A

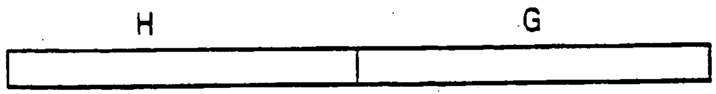


Fig. 24B

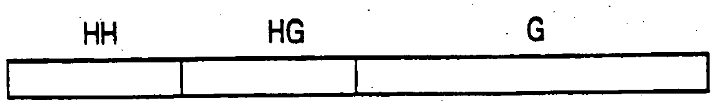


Fig. 24C

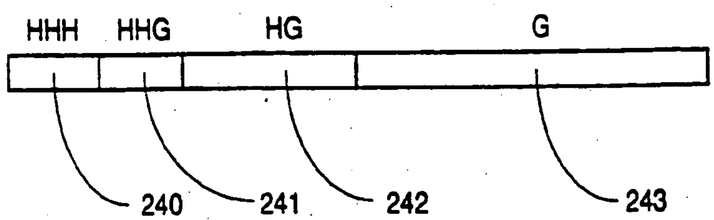
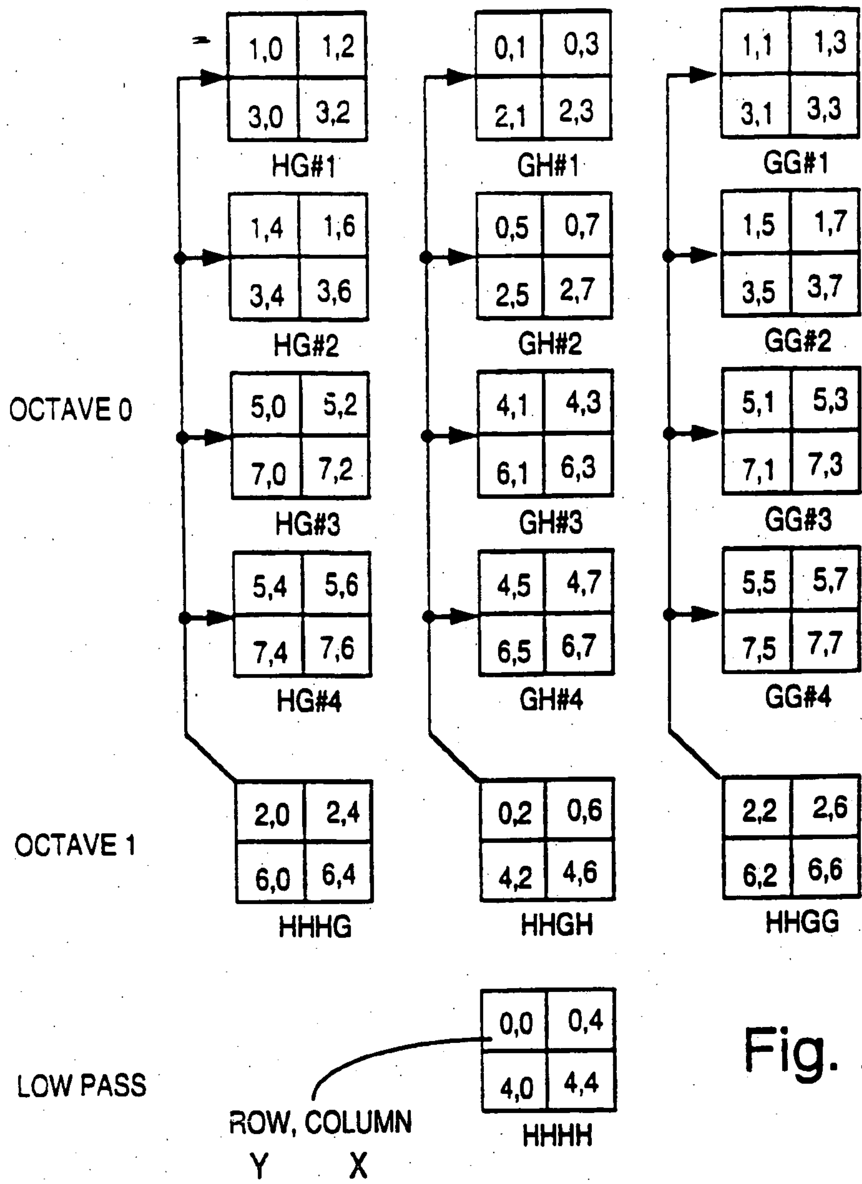
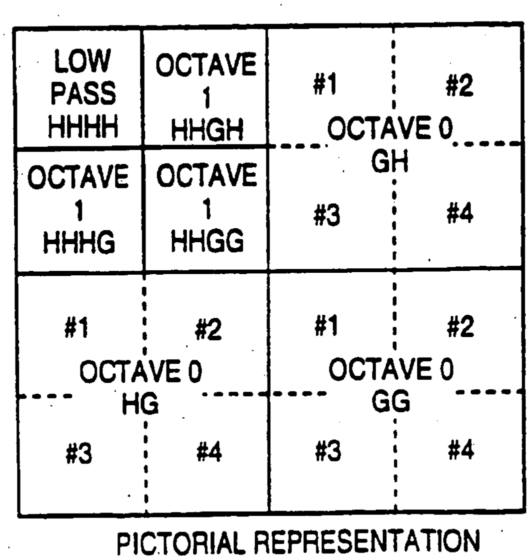


Fig. 24D



OCTAVE 0
1,0 1,2 3,0 3,2
HG#1
0,1 0,3 2,1 2,3
GH#1
1,1 1,3 3,1 3,3
GG#1
1,4 1,6 3,4 3,6
HG#2
0,5 0,7 2,5 2,7
GH#2
1,5 1,7 3,5 3,7
GG#2
5,0 5,2 7,0 7,2
HG#3
4,1 4,3 6,1 6,3
GH#3
5,1 5,3 7,1 7,3
GG#3
5,4 5,6 7,4 7,6
HG#4
4,5 4,7 6,5 6,7
GH#4
5,5 5,7 7,5 7,7
GG#4
OCTAVE 1
2,0 2,4 6,0 6,4
HHHG
0,2 0,6 4,2 4,6
HHGH
2,2 2,6 6,2 6,6
HHGG
LOW PASS
ROW, COLUMN
Y X
0,0 0,4 4,0 4,4
HHHH

Fig. 25



LOW PASS HHHH
OCTAVE 1 HHGH
OCTAVE 1 HHHG
OCTAVE 1 HHGG
#1 #2 OCTAVE 0 GH #3 #4
#1 #2 OCTAVE 0 HG #3 #4
#1 #2 OCTAVE 0 GG #3 #4
PICTORIAL REPRESENTATION

Fig. 26

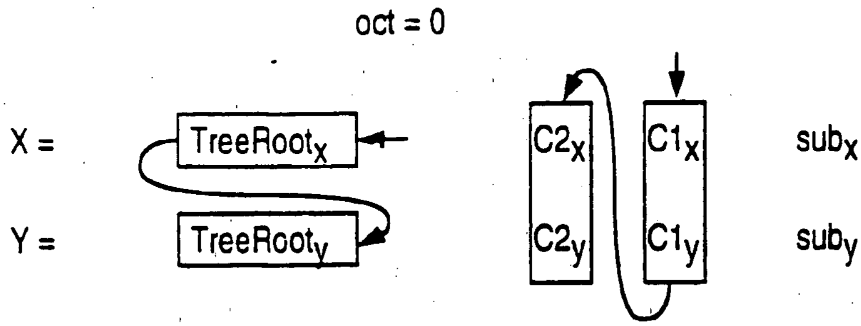


Fig. 27

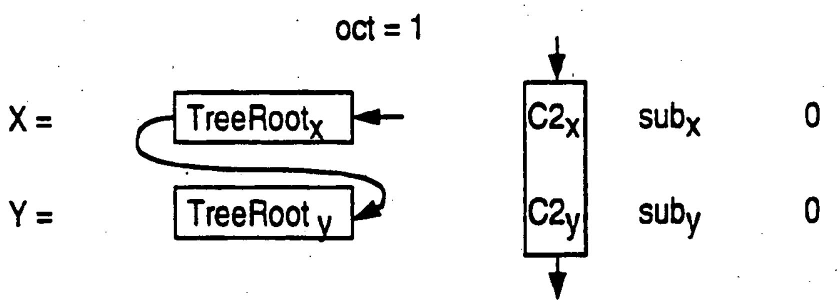


Fig. 28

	sub-band	sub_x	sub_y
low pass	HH	0	0
high pass	HG	0	1
	GH	1	0
	GG	1	1

Fig. 29

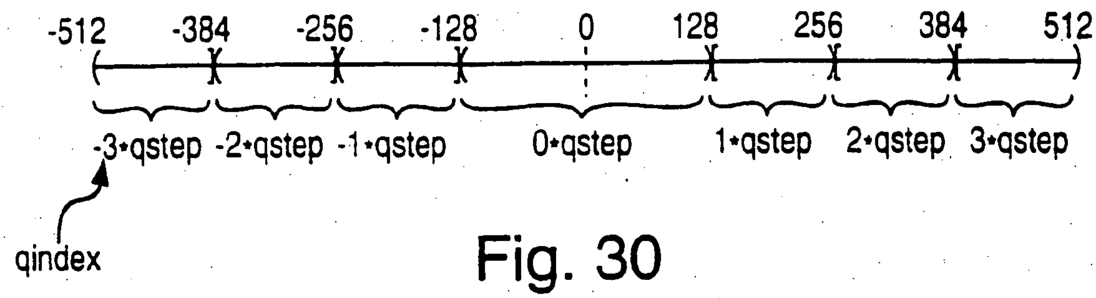

-512
-384
-256
-128
0
128
256
384
512
-3*qstep
-2*qstep
-1*qstep
0*qstep
1*qstep
2*qstep
3*qstep
qindex

Fig. 30

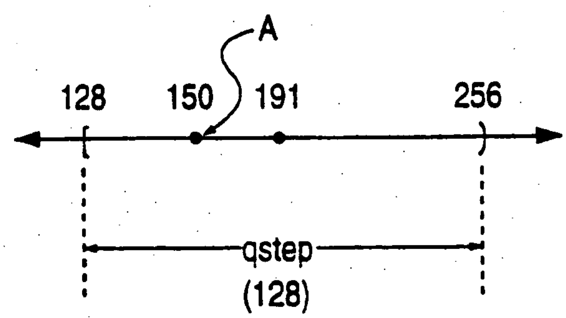

A
128
150
191
256
qstep
(128)

Fig. 31

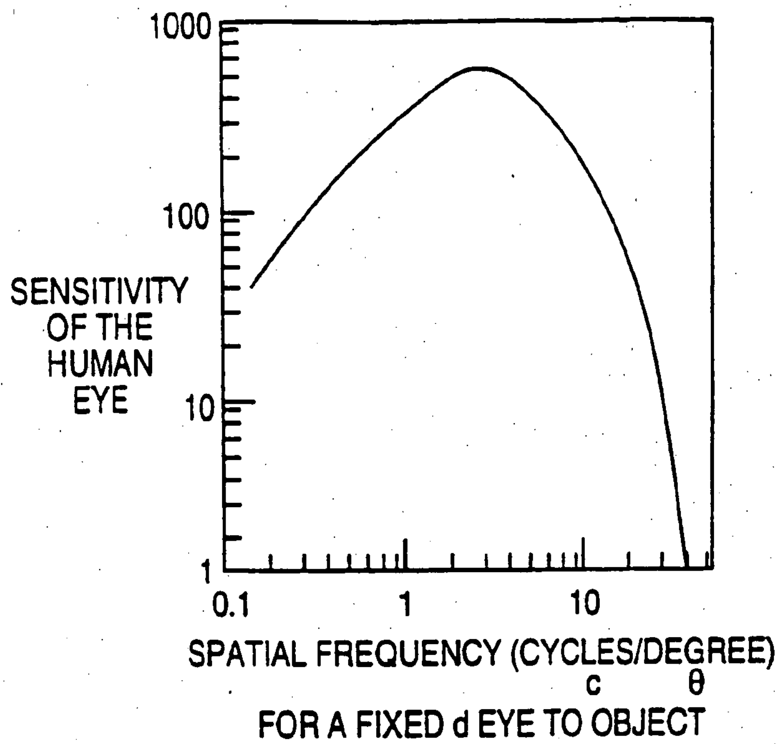

1000
100
10
1
SENSITIVITY OF THE HUMAN EYE
0.1
1
10
SPATIAL FREQUENCY (CYCLES/DEGREE)
c
θ
FOR A FIXED d EYE TO OBJECT

Fig. 32

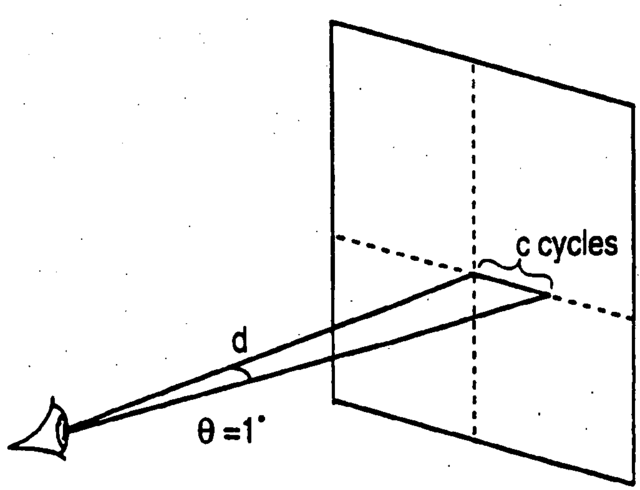

c cycles
d
θ =1°

Fig. 33

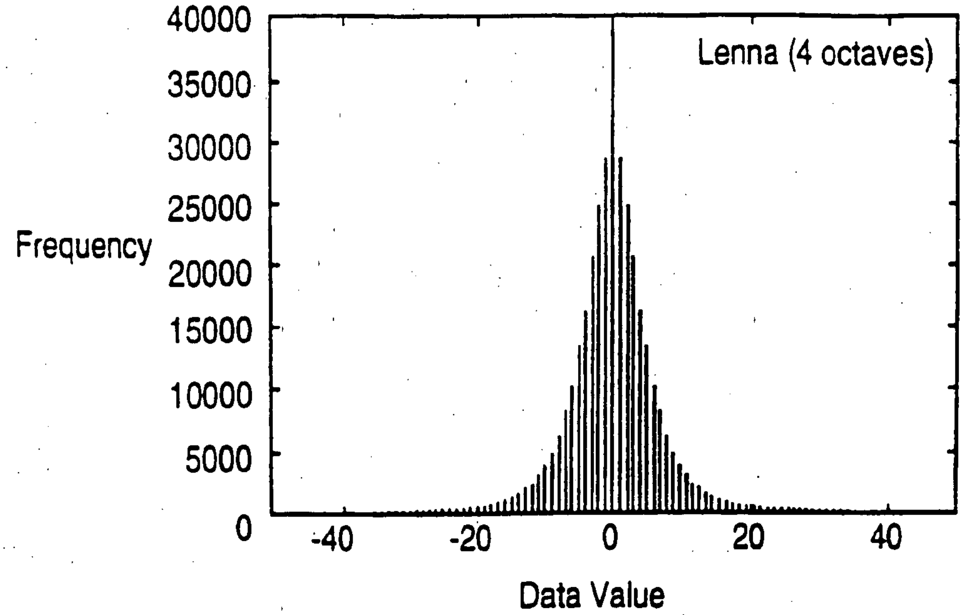

40000
35000
30000
25000
20000
15000
10000
5000
0
Frequency
Lenna (4 octaves)
-40
-20
0
20
40
Data Value

Fig. 34

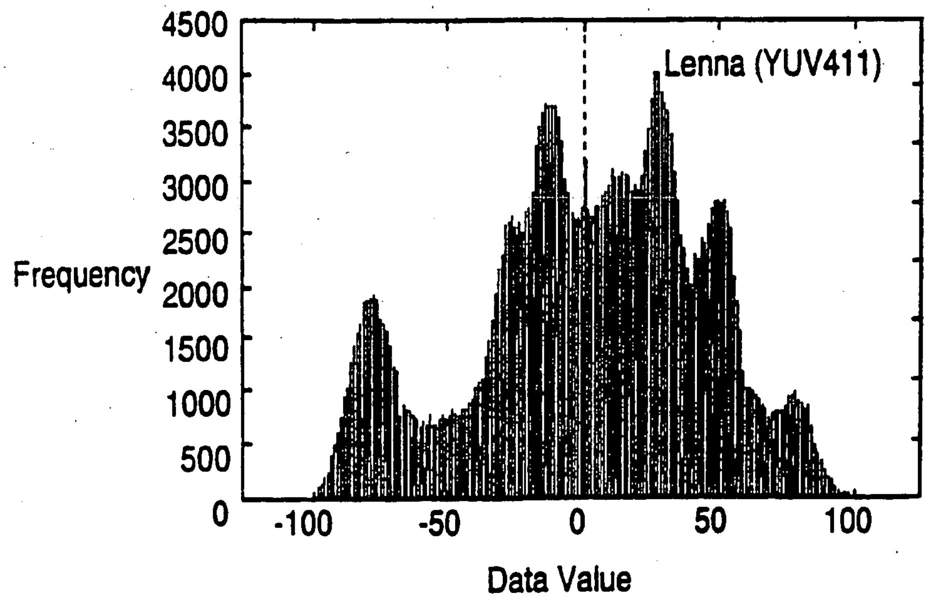

4500
4000
3500
3000
2500
2000
1500
1000
500
0
Frequency
Lenna (YUV411)
-100
-50
0
50
100
Data Value

Fig. 35

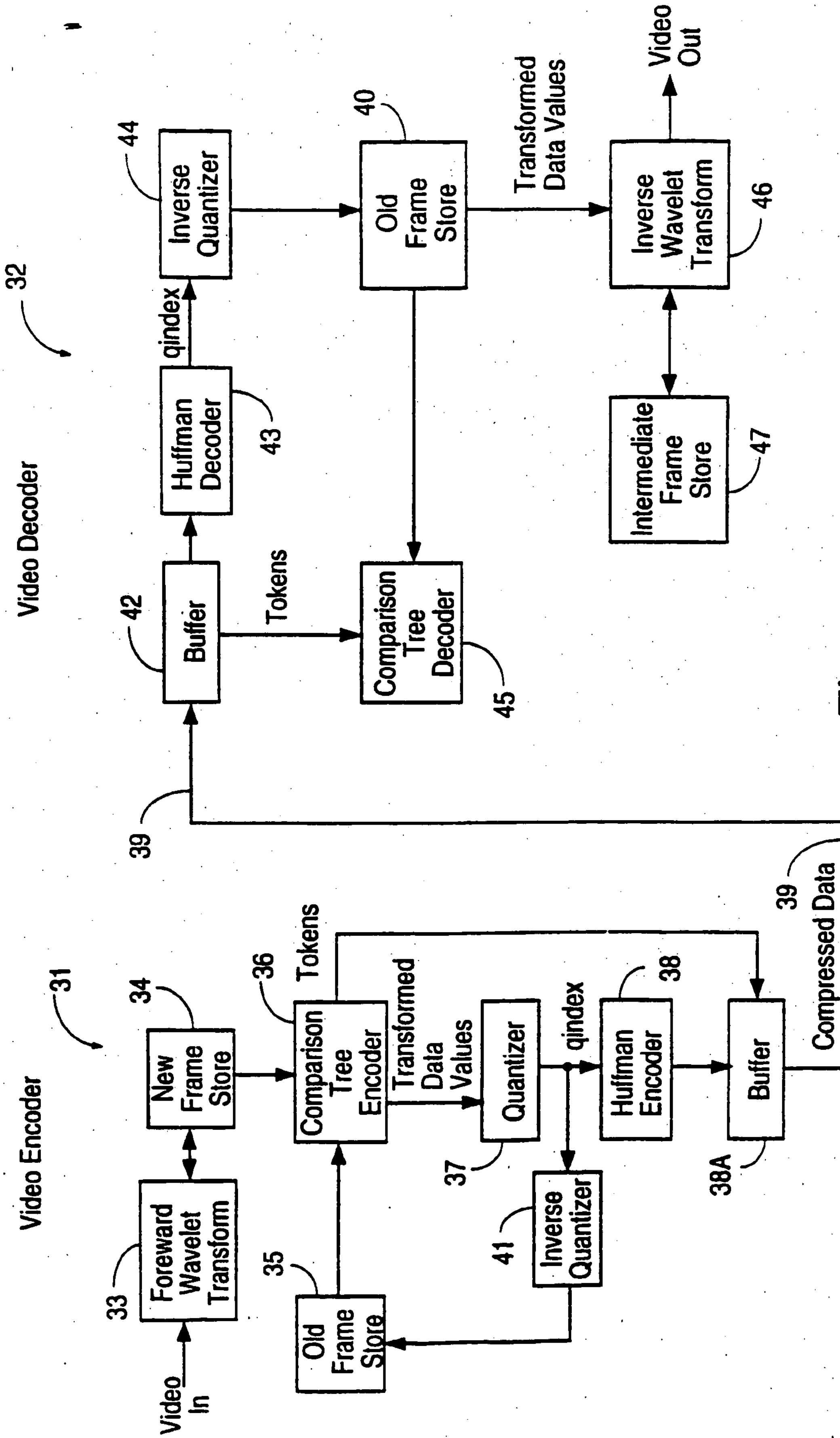

Video Encoder
31
Video In
33
Foreward Wavelet Transform
34
New Frame Store
36
Comparison Tree Encoder
Tokens
35
Old Frame Store
Transformed Data Values
37
Quantizer
qindex
41
Inverse Quantizer
38
Huffman Encoder
38A
Buffer
39
Compressed Data
39
Video Decoder
32
42
Buffer
Tokens
43
Huffman Decoder
qindex
44
Inverse Quantizer
45
Comparison Tree Decoder
40
Old Frame Store
Transformed Data Values
46
Inverse Wavelet Transform
Video Out
47
Intermediate Frame Store

Fig. 36

MODES OF VIDEO ENCODER AND
VIDEO DECODER

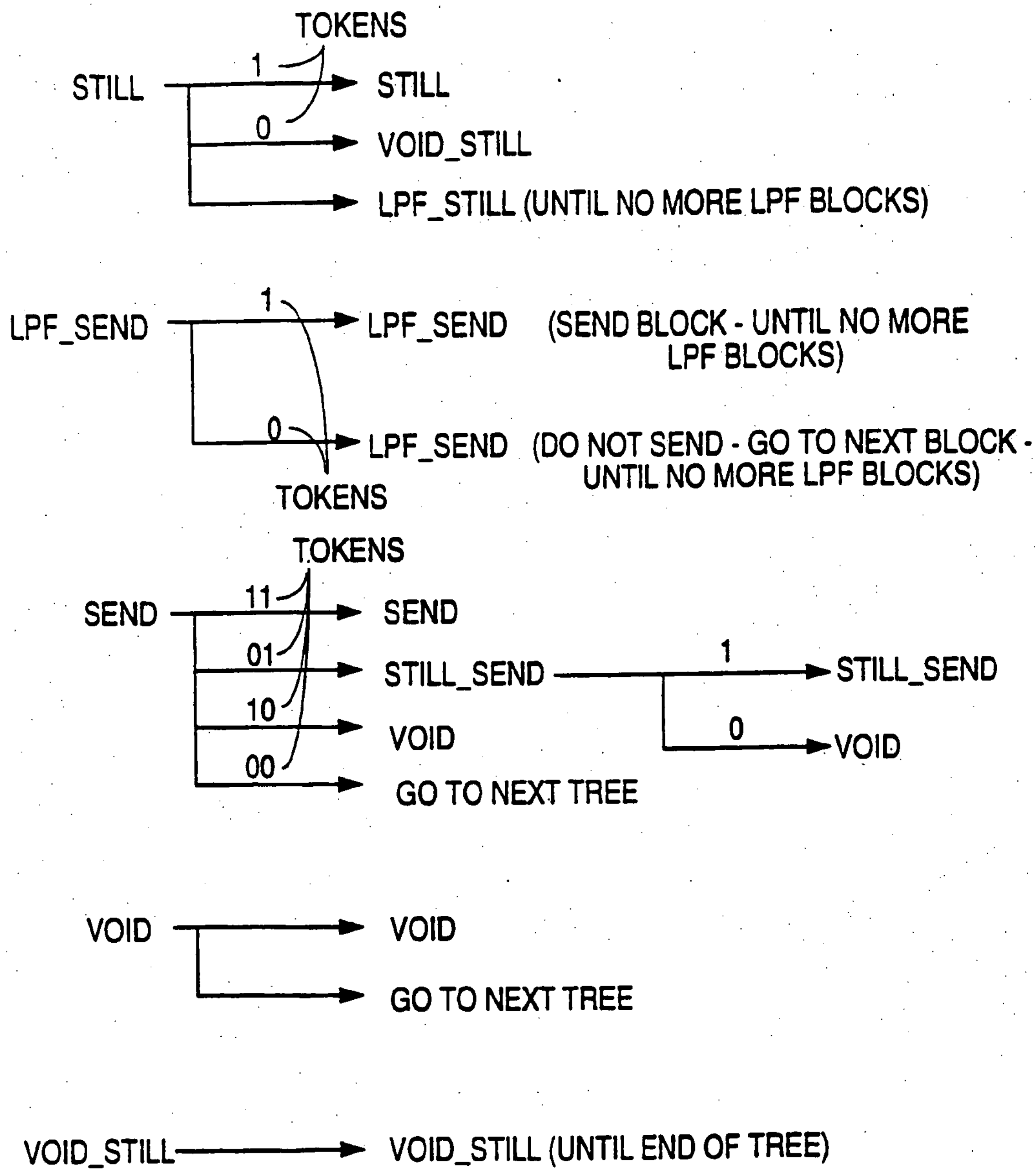


Fig. 37

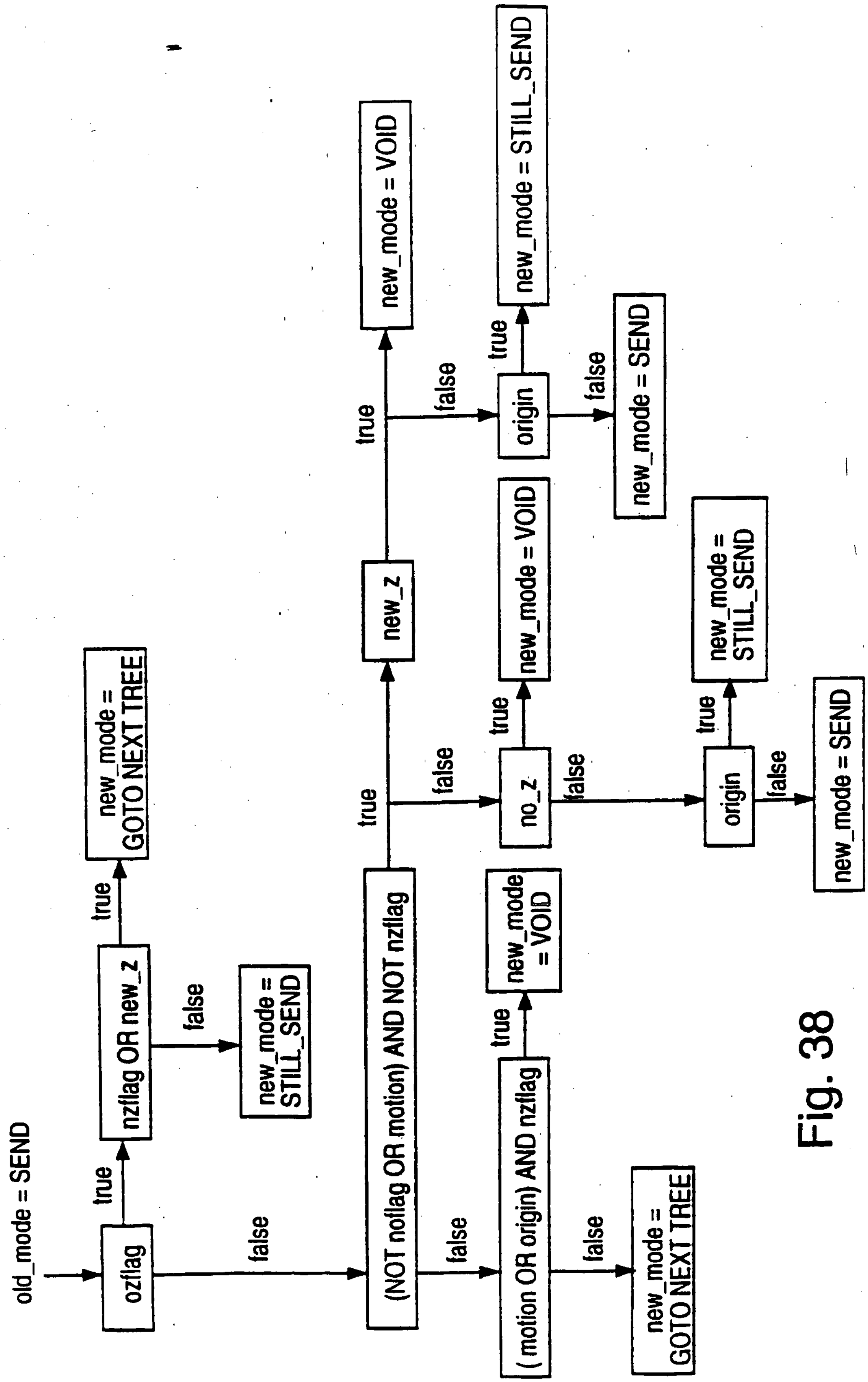

old_mode = SEND
ozflag
true
false
nzflag OR new_z
true
false
new_mode = GOTO NEXT TREE
new_mode = STILL_SEND
(NOT noflag OR motion) AND NOT nzflag
true
false
new_z
true
false
new_mode = VOID
origin
true
false
new_mode = STILL_SEND
new_mode = SEND
no_z
true
false
new_mode = VOID
origin
true
false
new_mode = STILL_SEND
new_mode = SEND
(motion OR origin) AND nzflag
true
false
new_mode = VOID
new_mode = GOTO NEXT TREE

Fig. 38

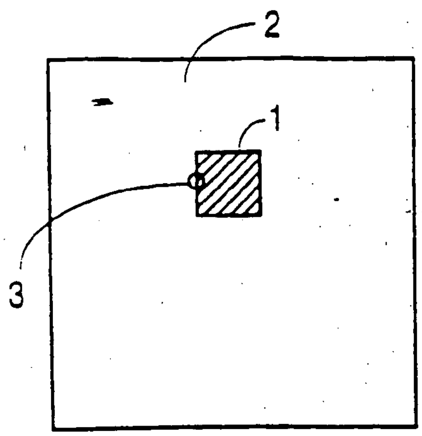


Fig. 39

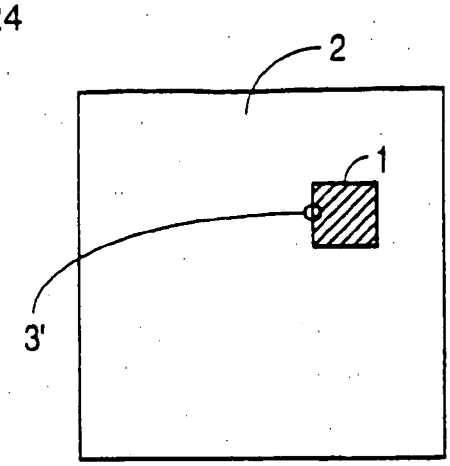


Fig. 40

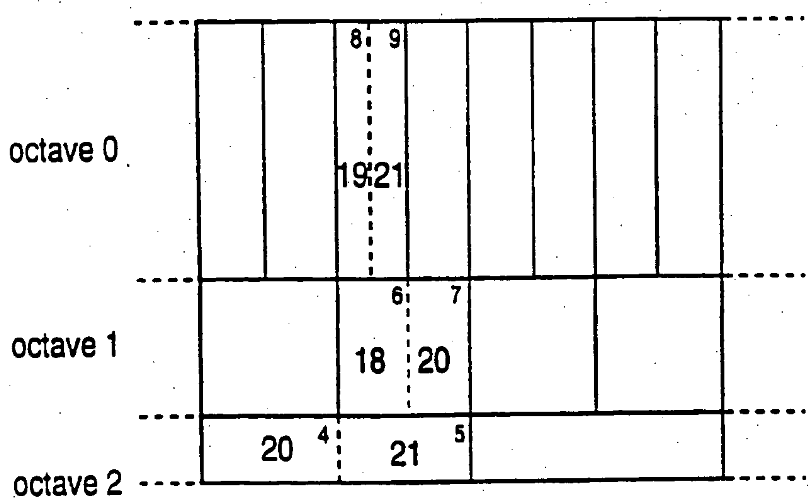


Fig. 41

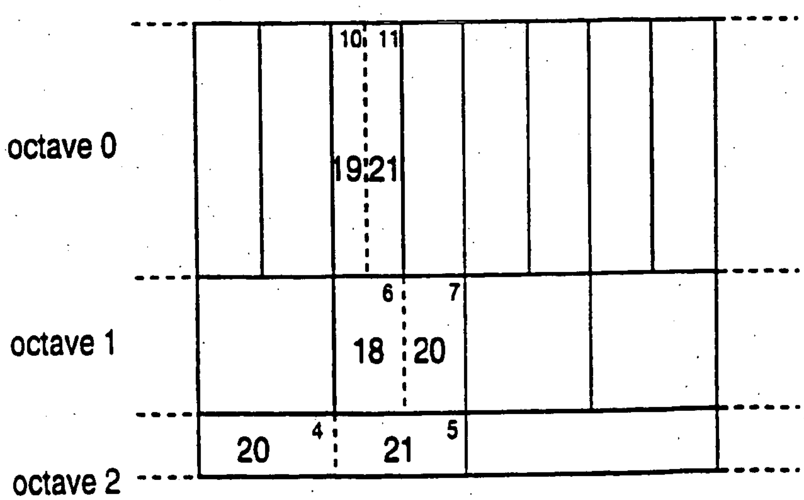


Fig. 42

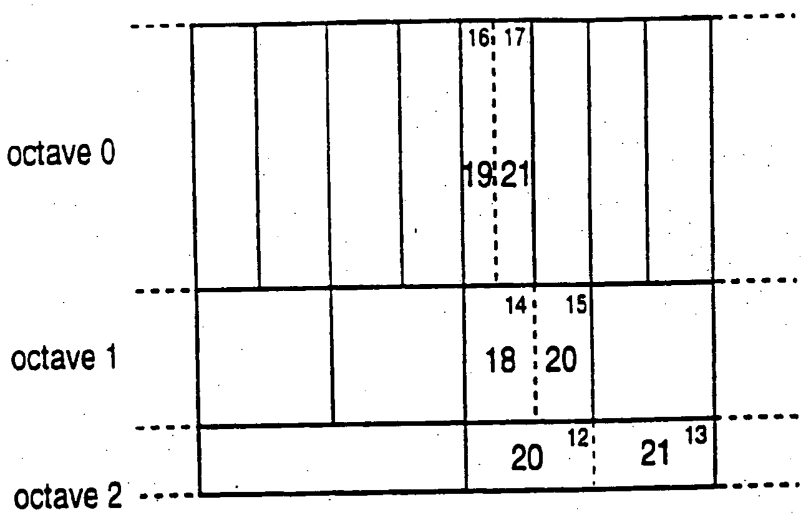


Fig. 43

VARIABLE - LENGTH TOKENS

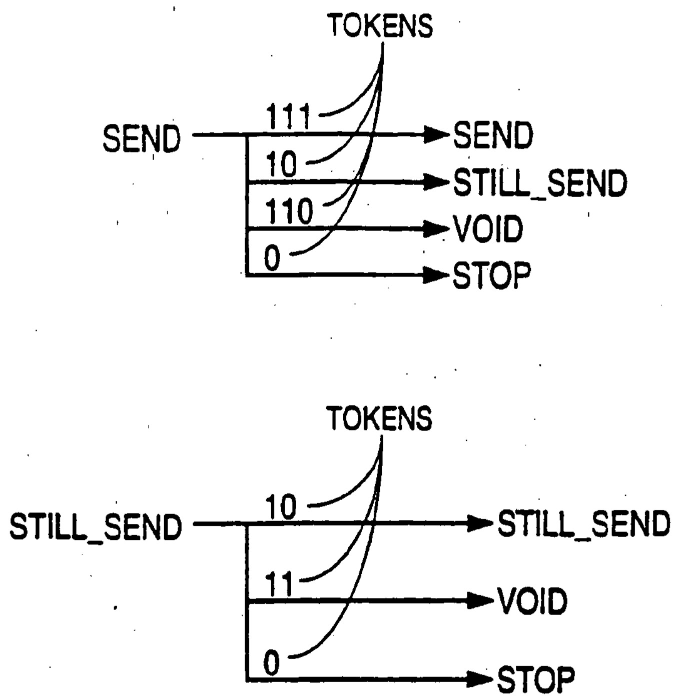


FIG. 44